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THE OBLIQUE PROJECTION OF THE THORAX

AN ANATOMIC AND ROENTGENOLOGIC STUDY*

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THE rapid development of thoracic surgery has increased the demand upon the roentgenologist for accurate localization of lesions within the thorax. The surgeon requires detailed information as to the distribution of bronchi and lobes in each lung if he is to appreciate the location and extent of a lesion, and decide upon the procedure best suited for its successful treatment.

By means of bronchography, the roentgen orientation of abnormalities in relation to the bronchial tree has become practicable. The normal superimposition of the several pulmonary lobes in the anteroposterior axis produces a complex bronchial mosaic in the frontal view. Studies of the bronchial tree and lung fields in the frontal plane, stereoscopically, and in the lateral projection often do not afford the degree of visualization which is possible in the oblique projections.

We have found stereoscopic oblique projections often preferable in bronchograms to the usual routine frontal and lateral studies. By anterior oblique is meant a projection in the oblique posteroanterior axis, the film being parallel to the tangent of the right or the left pectoral mass and anterior axillary fold.

The oblique projection has long been recognized as of value in the study of cardiovascular lesions. Fragmentary material is available in the literature from which one may deduce the arrangement of the other intrathoracic structures in these planes. But, so far as we have been able to determine, the present type of material has not been utilized. For the purpose of better interpretation of such oblique projections, the anatomic study presented herein was pursued.

ANATOMIC STUDIES

Through the courtesy and with the assistance of the Department of Anatomy, the cadavers of two middle-aged males were frozen after being hardened by the injection of formalin alone. In this state, the torso was separated from the other parts and sectioned, one in the right anterior oblique, the other in the left anterior oblique (Figs. 1 and 2). The several slices so produced were approximately 1½ inches thick, parallel with the tangent of the respective breast and anterior axillary fold. Five major serial sections (excluding the extreme axillary portion) were used from each.

One of us recently had the opportunity to see some roentgen studies of cross-section anatomic material prepared by Ma-

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honey and Anson. Our sections were about three times the thickness of theirs. Roentgenograms were made of each slice while still in the solid state.

Subsequently the sections were defrosted and preserved in alcohol. The roentgenographic studies were then carefully checked against the anatomic material for accurate identification and orientation of the several

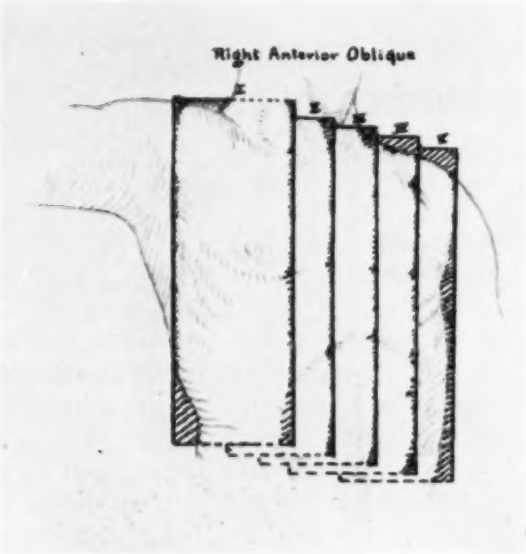

Fig. 1. Diagram of sections cut in the right anterior oblique, as presented in Figures 3*a*–8, inclusive. (Adapted from the Manual of Surgical Anatomy.)

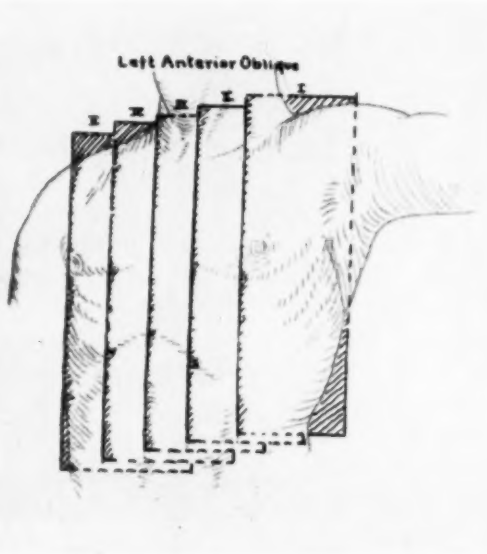

Fig. 2. Diagram of sections cut in the left anterior oblique, as presented in Figures 9*a*–14, inclusive. (Adapted from the Manual of Surgical Anatomy.)

structures appearing in each segment. The diagrammatic tracing of the roentgenogram of each of the sections is shown with its respective film in Figures 3*a*–7*b* and 9*a*–13*b*, inclusive. Based upon these tracings when superimposed and registered, a composite diagram of the right (Fig. 8) and the left (Fig. 14) anterior oblique projections was formulated.

The coincidence of a consolidated left inferior lobe in one cadaver, and a consolidated right superior lobe in the other was fortunate for the roentgenographic demonstration of the lobar boundaries.

THE RIGHT ANTERIOR OBLIQUE PROJECTION

The *right anterior oblique* projection (Figs. 3*a*–8) affords the maximum visibility of the posterior right lung field. In bronchography it displays the left bronchial tree to a maximum advantage. The major portion of the projected thorax is occupied by the right lung, the left being foreshortened.

The periphery of the long *interlobar*, or *chief pleural fissure* on the right courses in a constantly changing plane from the level of the third thoracic vertebral body posteriorly, lateralward to the fourth rib, following that rib forward to the middle of the axilla, thence downward to reach the sixth rib mesial to the anterior axillary line. The plane of its surface sweeps from superiorly, facing slightly leftward to an almost horizontal axis in the axilla, and then sharply shifts into a frontovertical position behind the middle lobe.

The *accessory*, or *middle fissure*, as it extends anteriorly from the chief fissure, maintains an almost horizontal plane throughout, conforming in general to the level of the fourth rib.

The right *superior lobe* is so projected that it occupies the major portion of the upper diagonal half of the chest, overlying the trachea and great vessels below the level of the carina. The *middle lobe* overlies

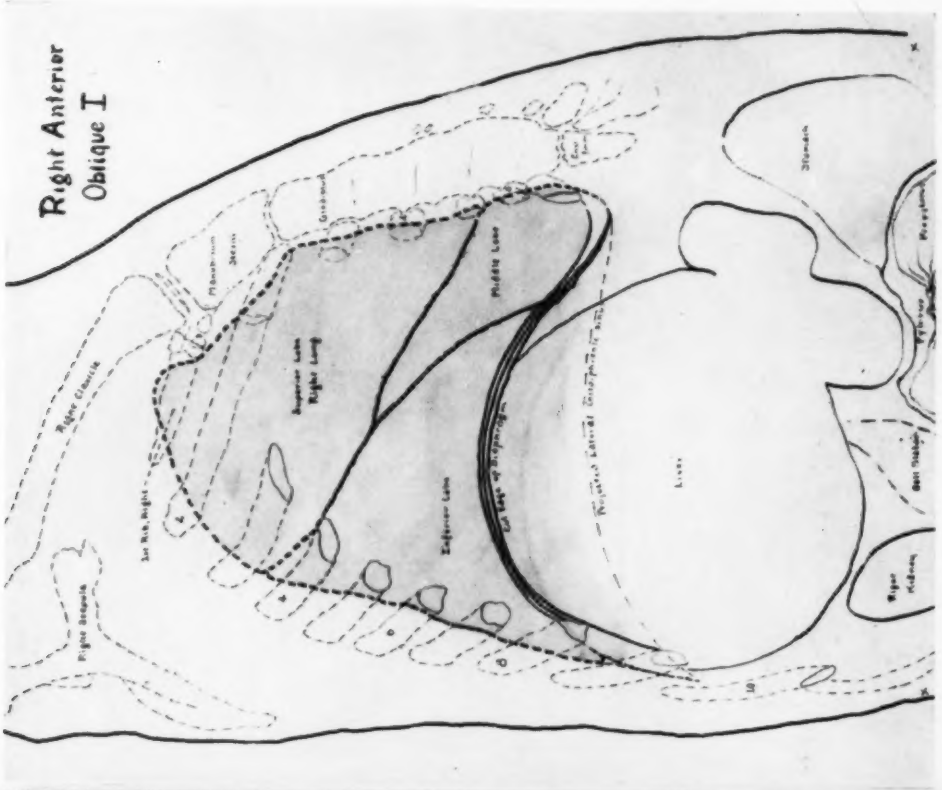

Fig. 3b. Diagram of structures shown in Figure 3a.

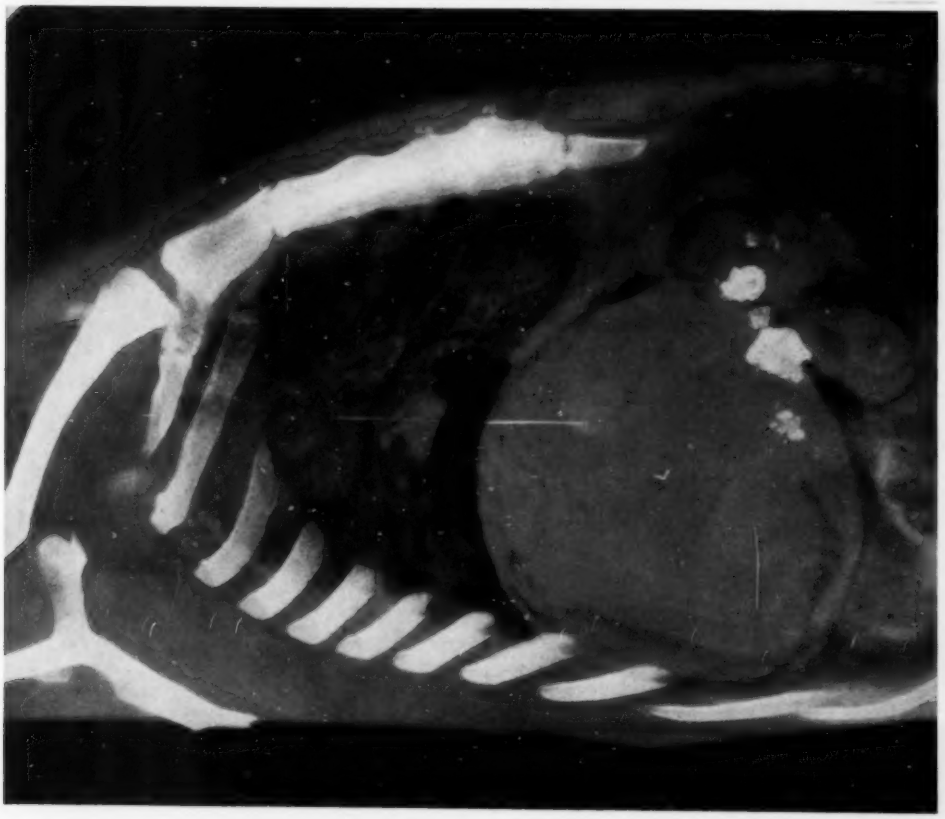

Fig. 3a. Roentgenogram of section 1, right anterior oblique projection.

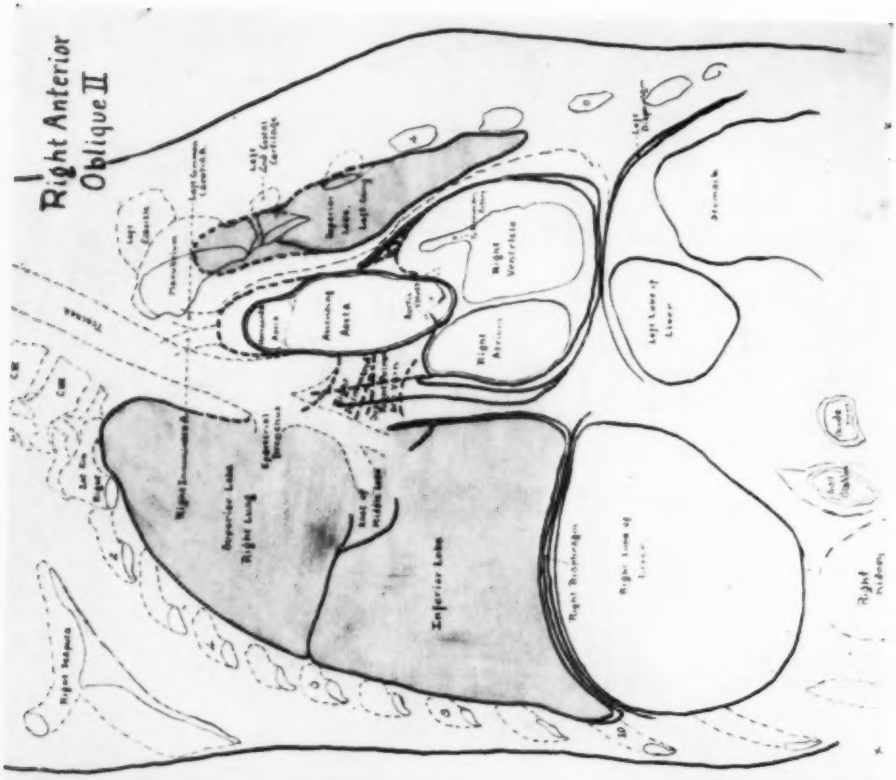

FIG. 4b. Diagram of structures shown in Figure 4a.

FIG. 4a. Roentgenogram of section II, right anterior oblique projection.

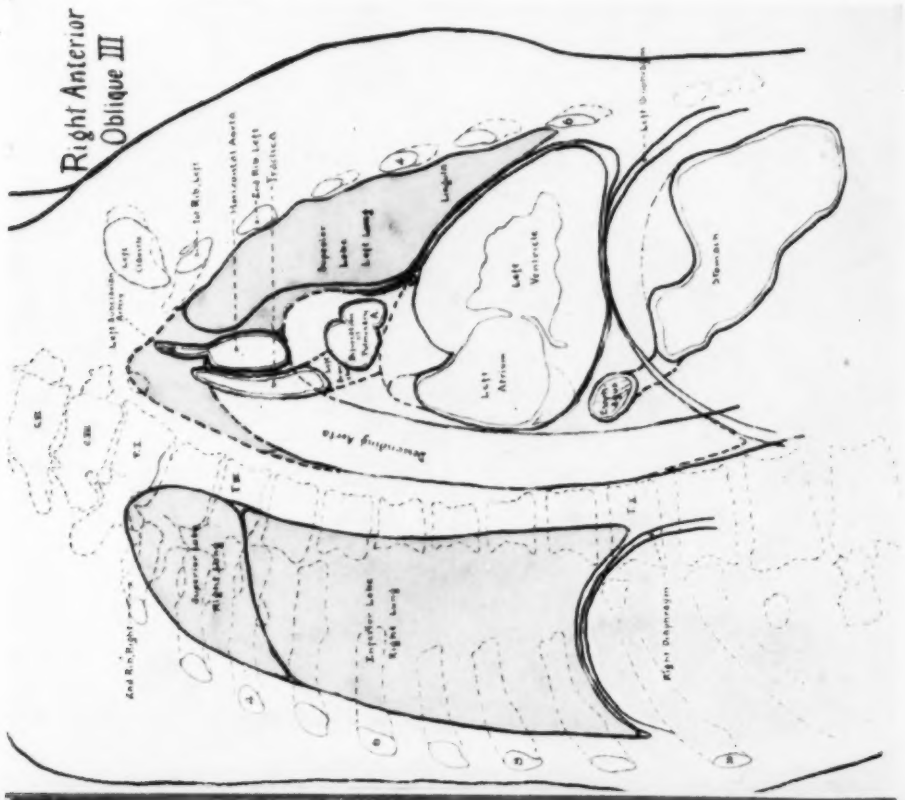

Fig. 5b. Diagram of structures shown in Figure 5a.

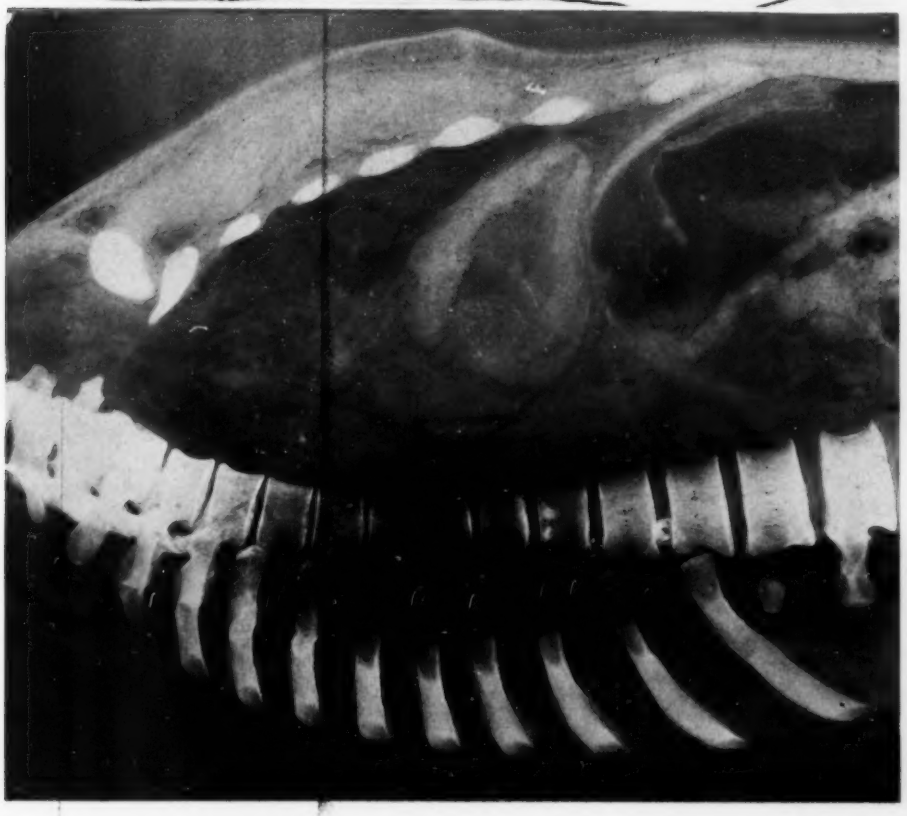

Fig. 5a. Roentgenogram of section III, right anterior oblique projection.

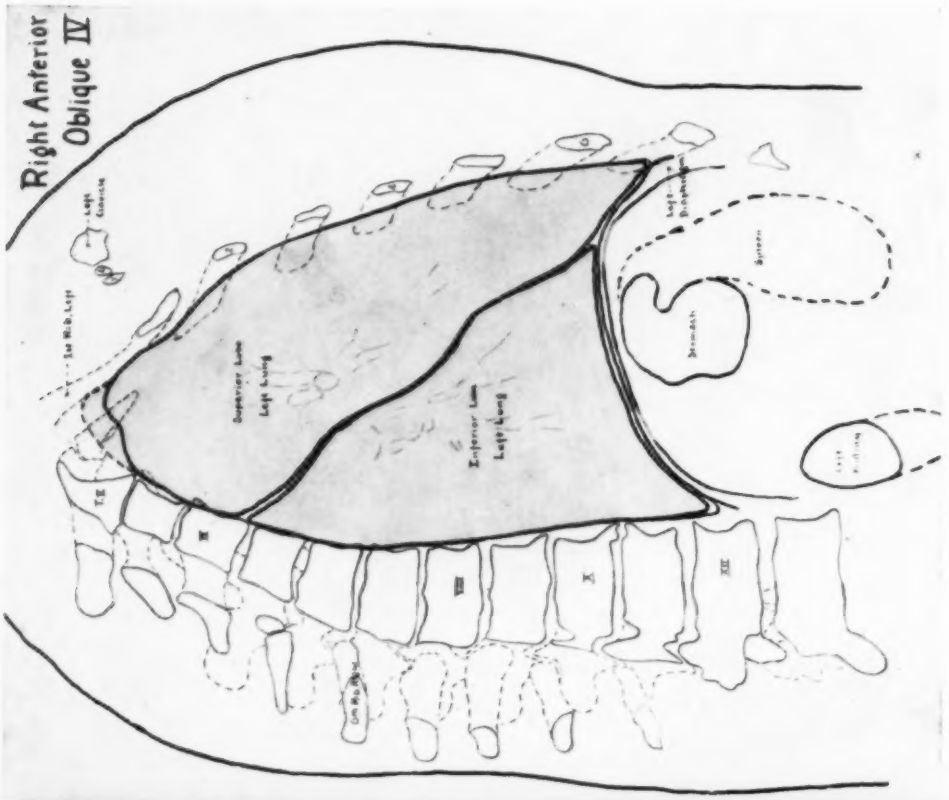

FIG. 6b. Diagram of structures shown in Figure 6a.

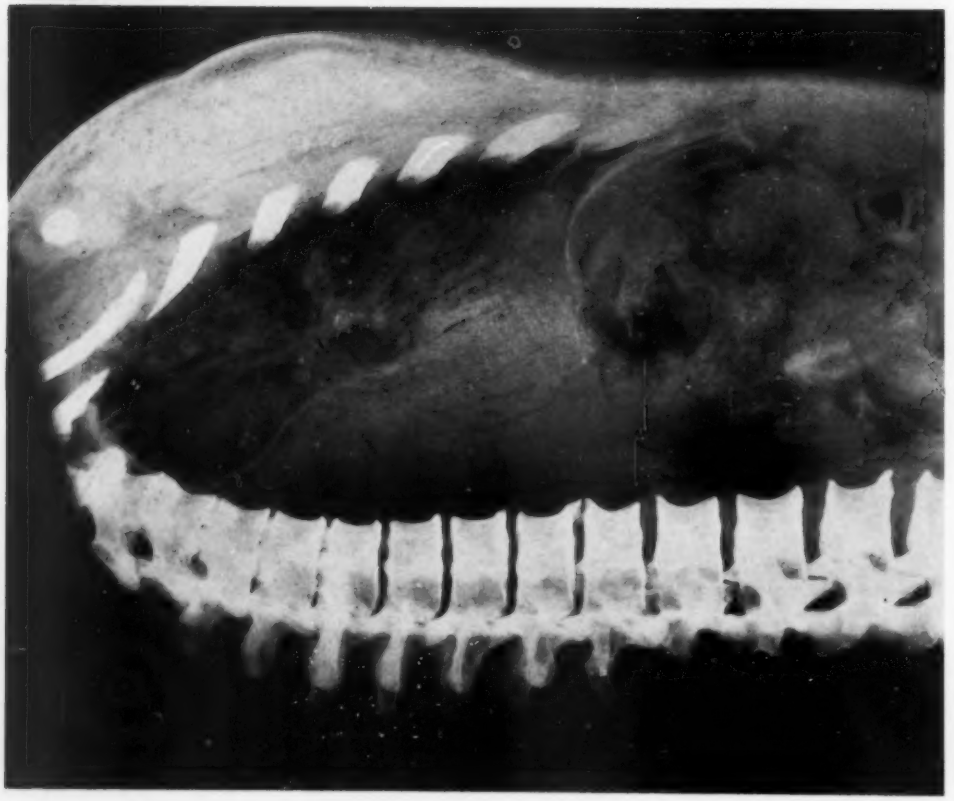

FIG. 6a. Roentgenogram of section IV, right anterior oblique projection.

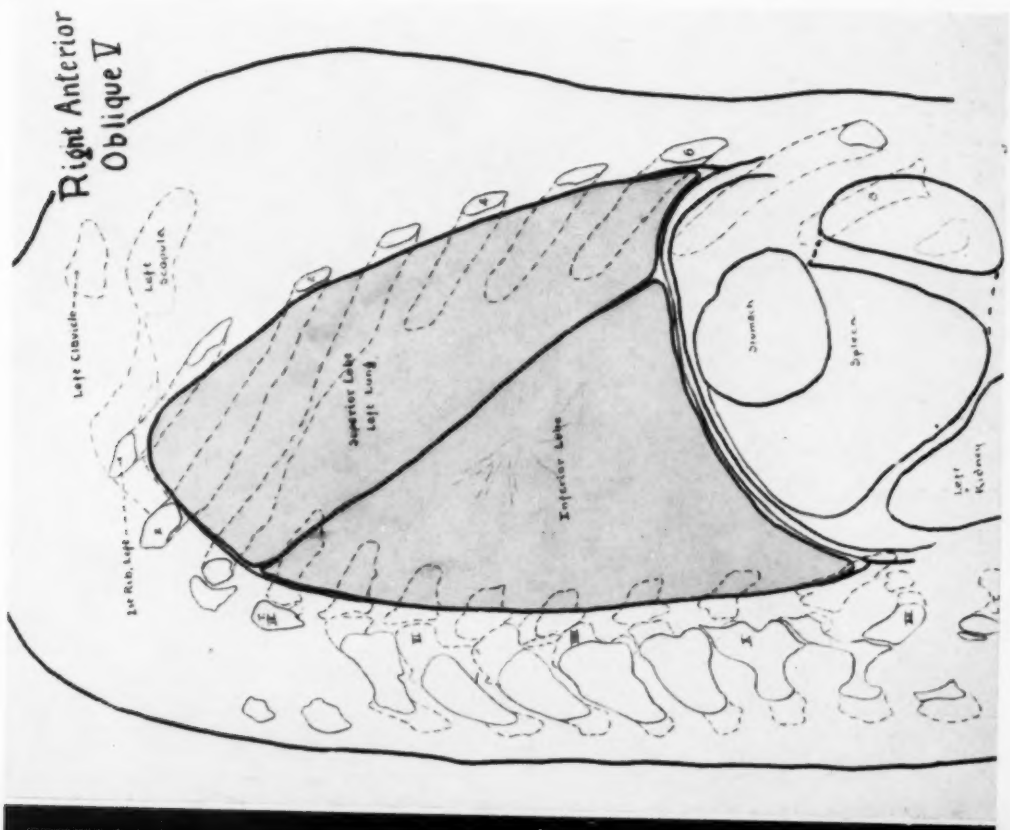

Fig. 7*b*. Diagram of structures shown in Figure 7*a*.

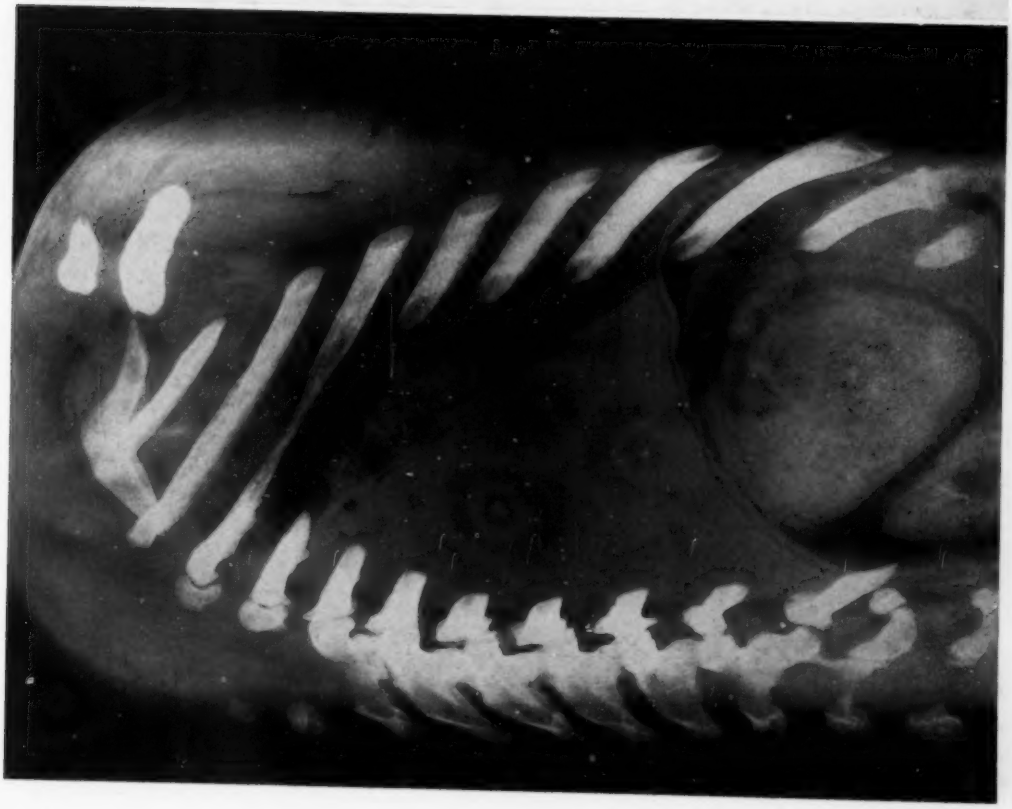

Fig. 7*a*. Roentgenogram of section v, right anterior oblique projection.

the right half of the heart shadow, in apposition to the right atrium.

The *left interlobar fissure* is projected in a narrow plane diagonally from the fourth thoracic vertebral body to the posterolateral intersection of the seventh rib and the diaphragm.

The posterolateral portions of the *left lung* are largely obscured by the mediastinum, great vessels and heart; the anterolateral segment, especially the lingula, being well visualized.

The posterolateral right and the anterolateral left costophrenic sinuses are visualized best in this plane.

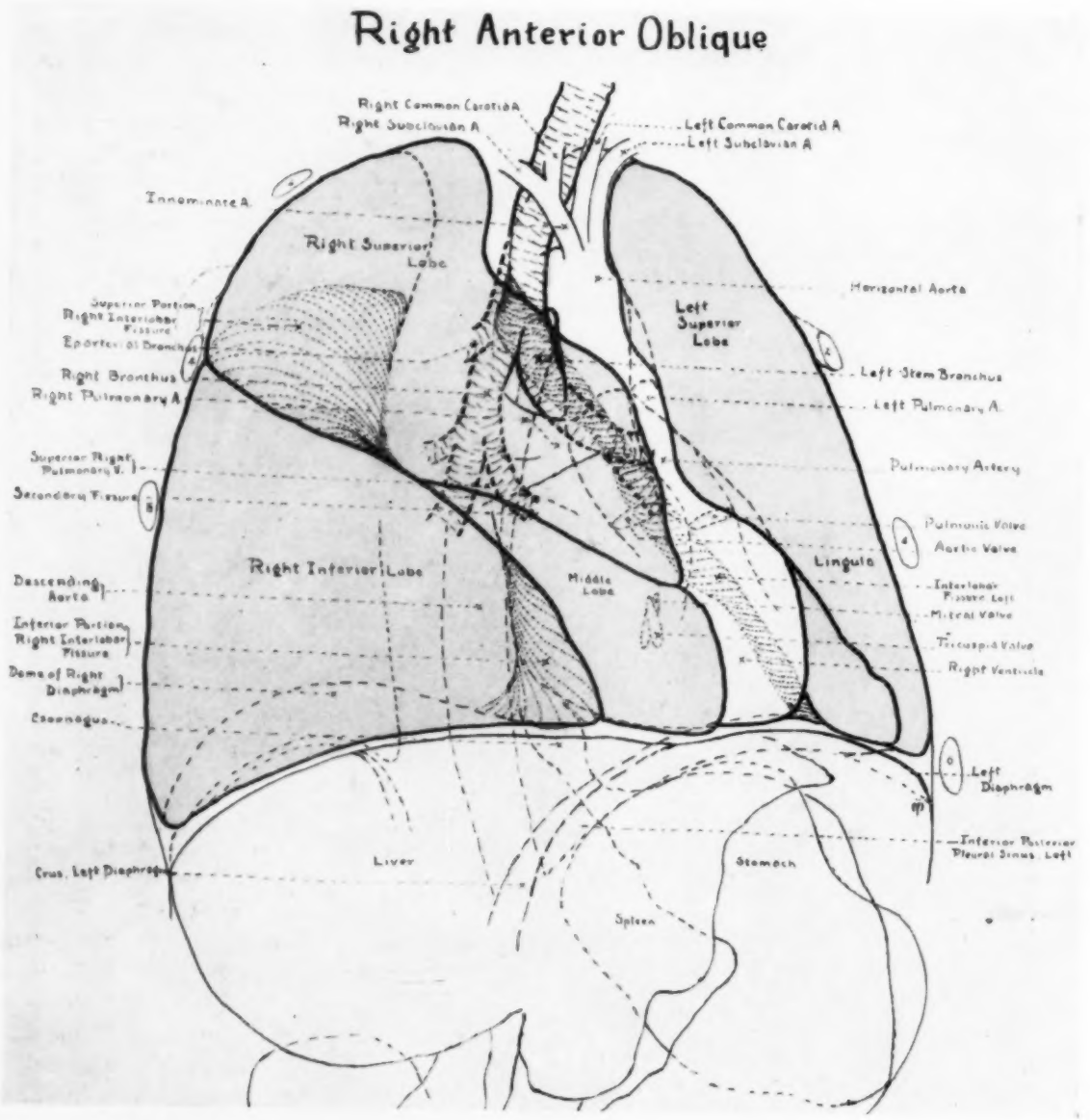

Fig. 8. Composite diagram of the structures to be visualized in the right anterior oblique projection of the thorax, based on Figures 3*a*–7*b*, inclusive.

Trachea and Bronchi. In the right oblique projection the *trachea* courses downward slightly to the right of the midline to divide

at the level of the fifth or sixth thoracic vertebra. The aortic impression on the trachea is not evident. The *left stem bronchus* extends downward, ventralward and to the left, passing posteroinferior to the left pulmonary artery, to divide into the superior and inferior left bronchi at the lateral margin of the bifurcation of the pulmonary artery. The left stem and its major branches, in the anatomic or frontal plane, divide and course predominantly in a narrow area with a sagittal axis. The oblique projection displays these bronchi in a plane at right angles to the roentgen beam, which affords a far better visibility of the entire left bronchial tree.

Heart and Great Vessels. In this projection the major cardiovascular mass is composed of the superimposed right and left atria on the right, and the superimposed ventricles on the left (Fig. 8). The mitral and tricuspid valves are in the same sagittal plane, the aortic and pulmonic in the same horizontal plane, the pulmonic toward the left.

The superior portion of the left cardiac mass is a projection of the pulmonary artery in profile. The right pulmonary artery, obscured by the ascending aorta in the frontal projection, and the right pulmonary veins may be brought into view in this oblique projection. The ascending aorta will overlie the descending aorta, with the horizontal portion of the arch commonly in optical section. The innominate, left common carotid, and left subclavian arteries are projected to the left of the trachea, the superior vena cava overlying the last but not readily visualized by means of any differential density.

LEFT ANTERIOR OBLIQUE PROJECTION

General. The *left anterior oblique* projection (Figs. 9*a*–14) affords the maximum visibility of the left lung field and the right bronchial tree. The *left superior lobe* is projected to the right of the midline overlying the arch of the aorta, the great vessels, trachea and primary bronchi. The *lingula* of the superior lobe overlies the pulmonary conus, the left atrium, and in some extent the left ventricular apex.

The *left interlobar fissure* in general describes a sweeping plane similar to the chief fissure on the right. Its degree of slope is greater, however, with resultant lessened visibility. The *right accessory fissure* normally is not prominent due to the gentle obliquity of its slope from above downward and forward. The *right chief fissure* occupies a foreshortened plane largely covered by the aorta and heart.

The right anterolateral and the left posterolateral costophrenic sinuses are best visualized in this projection.

Trachea and Bronchi. The *trachea* occupies the midline, passing between the "fork" formed by the innominate artery and superior vena cava on the right and the common carotid and subclavian arteries on the left. The arc of the trachea, as it passes posterior and to the right of the horizontal portion of the aortic arch, is accentuated. The *left stem bronchus* overlies the right slightly, immediately below the carina tracheae. The *right bronchial tree* is visualized to better advantage in this plane for reasons similar to those stated above in regard to the left in the right anterior oblique projection.

Heart and Great Vessels. As has been shown repeatedly in the literature since the advent of roentgenology, the left anterior oblique view affords the maximum individual visibility of the right ventricle and the left chambers of the heart and of the aortic arch. In this plane the *interventricular septum* is superimposed upon the *interatrial septum* (Fig. 14). The branches of the aortic arch are separated to the maximum. The distribution of the left pulmonary artery is at its maximum visibility.

SYSTEMIC ANATOMY

Trachea and Bronchi. The distribution of the bronchial tree has been described by many authors. There is considerable diversity of terminology. The anatomic desig-

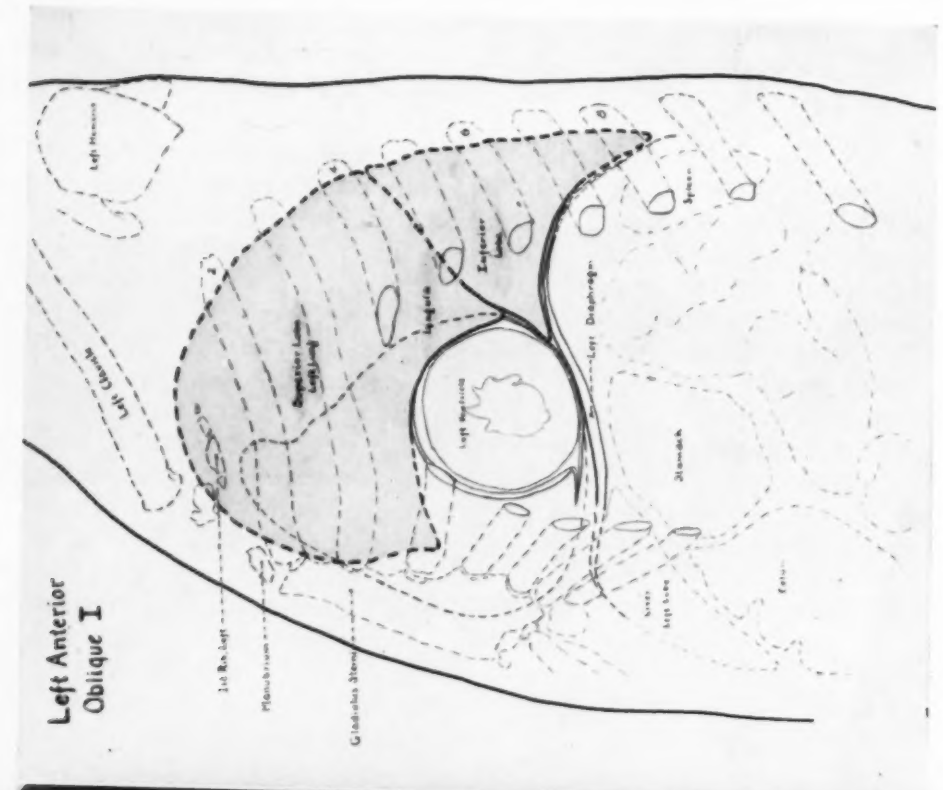

FIG. 9b. Diagram of structures shown in Figure 9a.

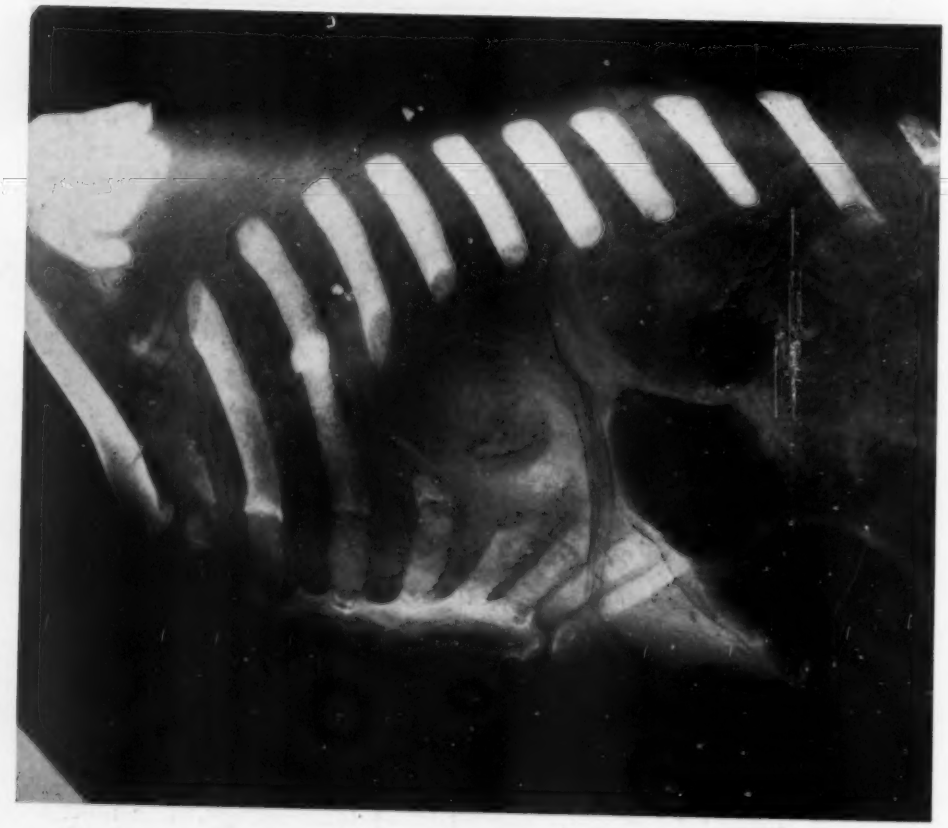

FIG. 9a Roentgenogram of section 1, left anterior oblique projection.

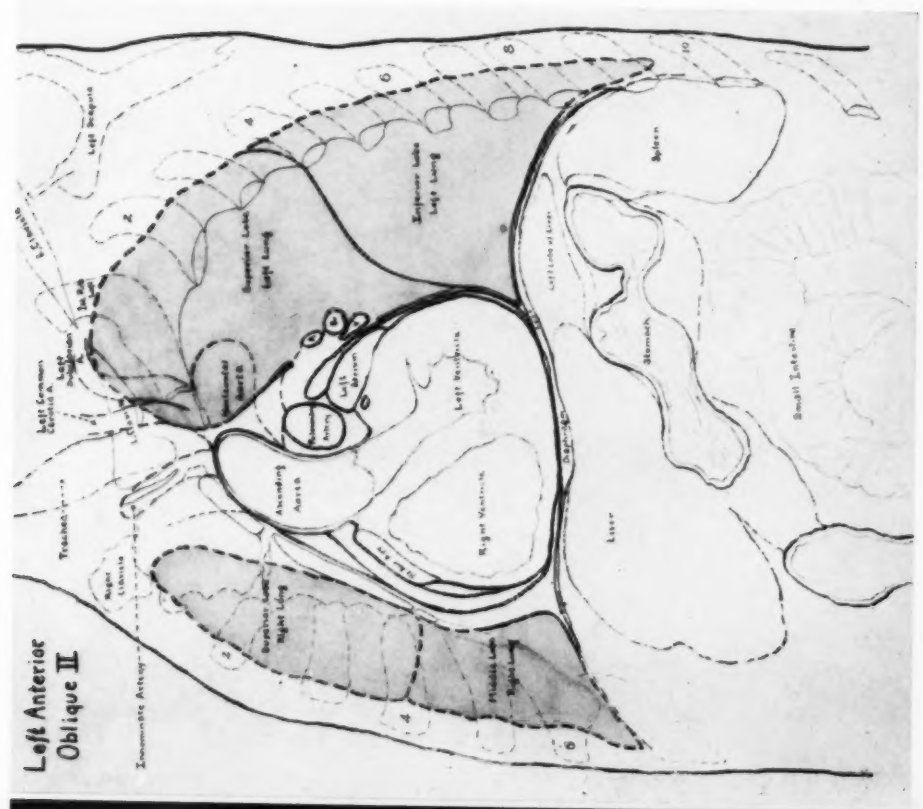

Fig. 10*b*. Diagram of structures shown in Figure 10*a*.

Fig. 10*a*. Roentgenogram of section II, left anterior oblique projection.

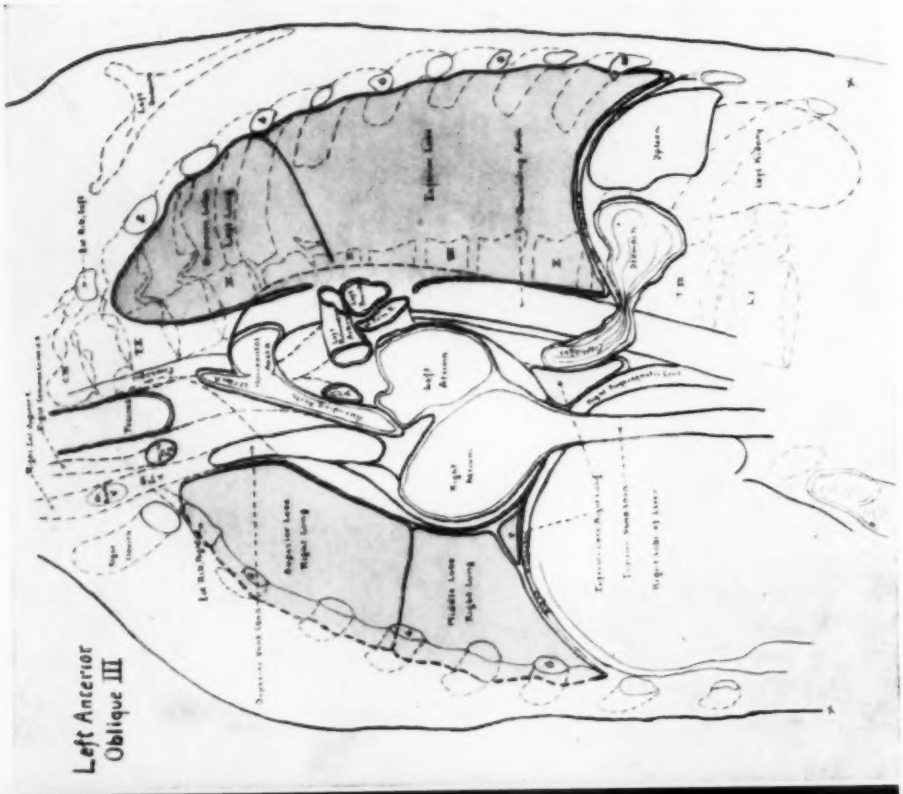

FIG. 11*b*. Diagram of structures shown in Figure 11*a*.

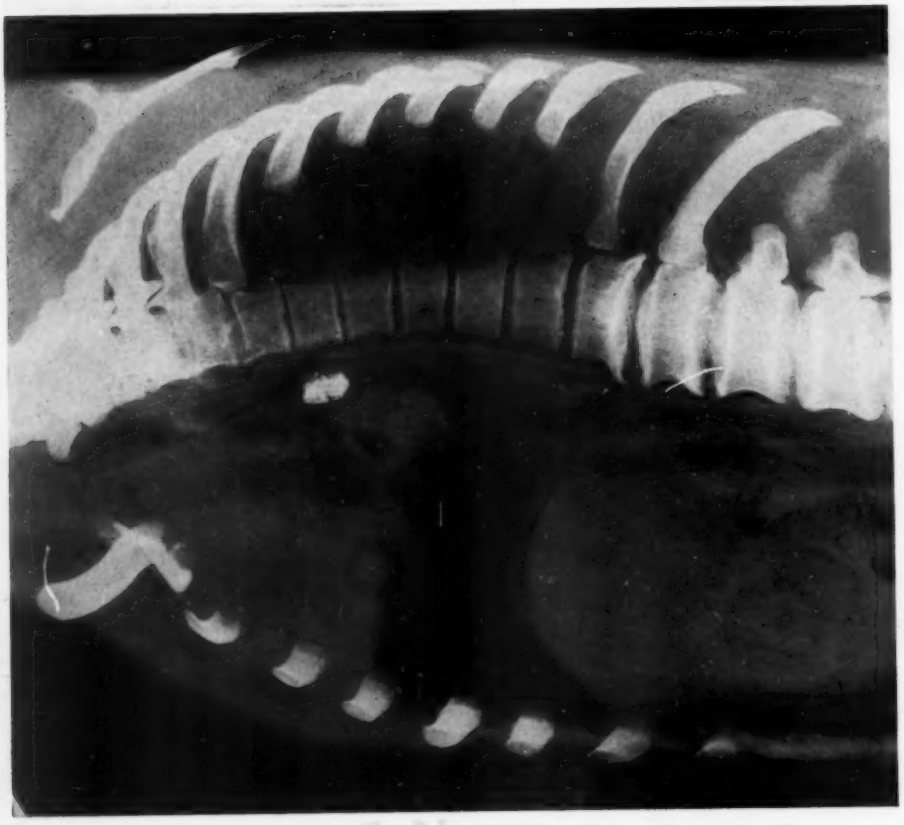

FIG. 11*a*. Roentgenogram of section III, left anterior oblique projection.

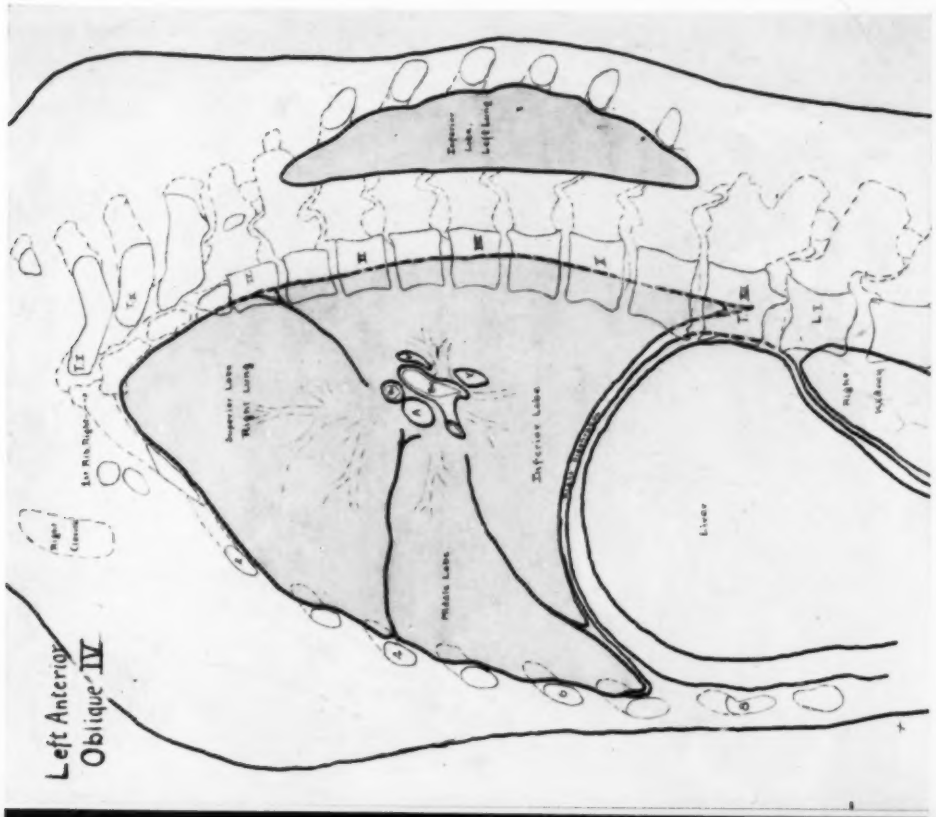

Fig. 12*b*. Diagram of structures shown in Figure 12*a*.

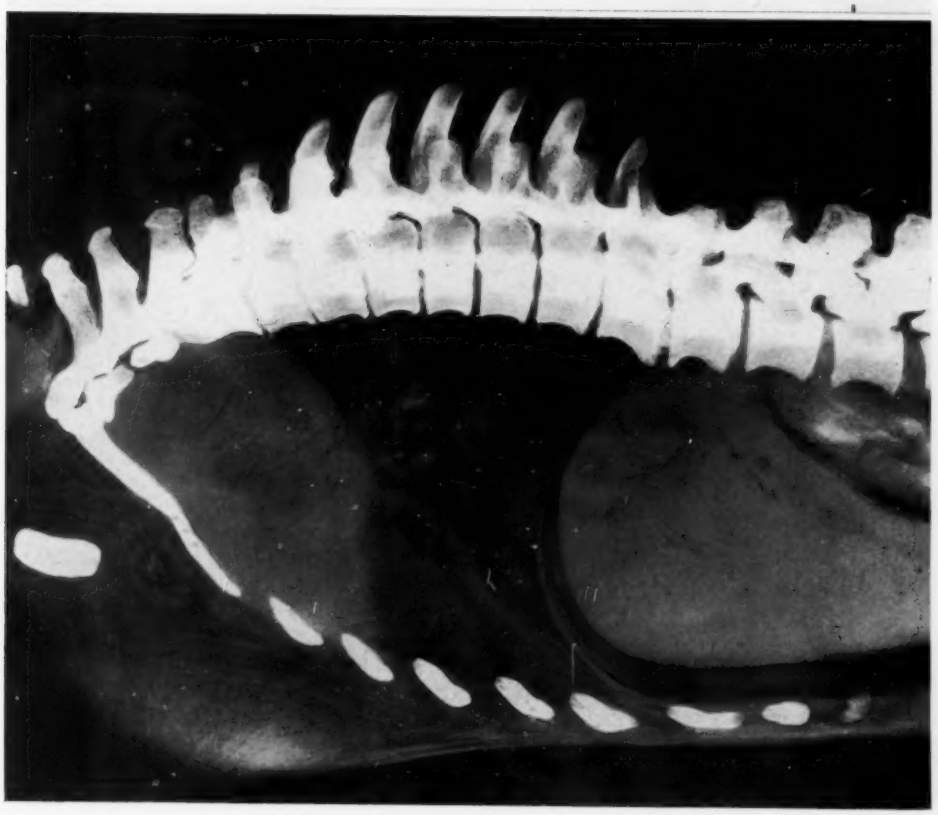

Fig. 12*a*. Roentgenogram of section IV, left anterior oblique projection.

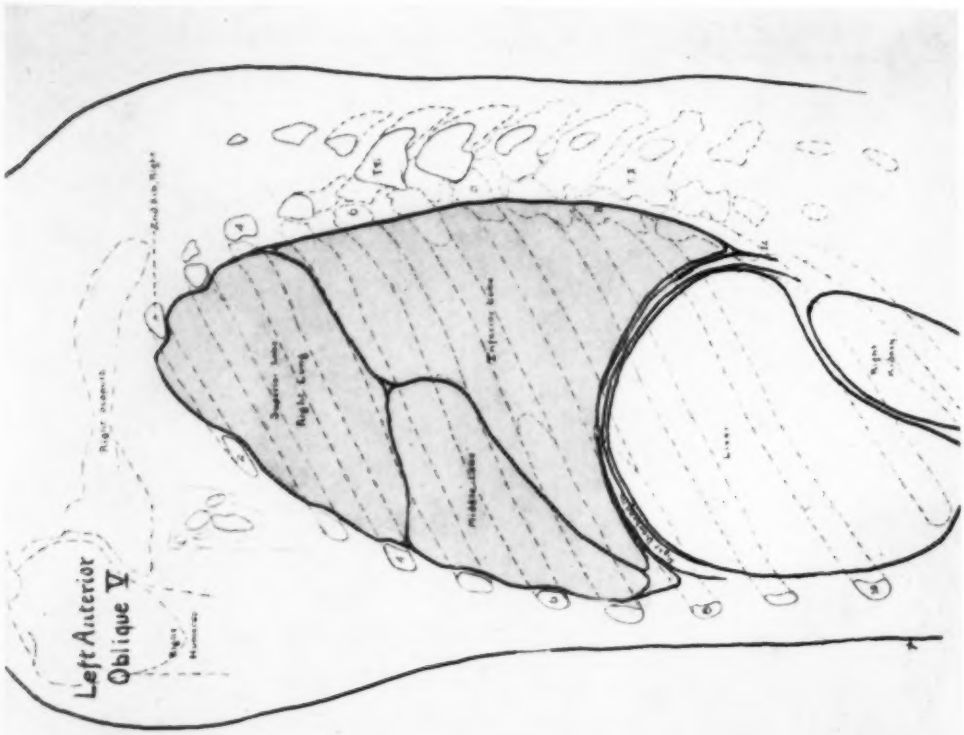

Fig. 13*b*. Diagram of structures shown in Figure 13*a*.

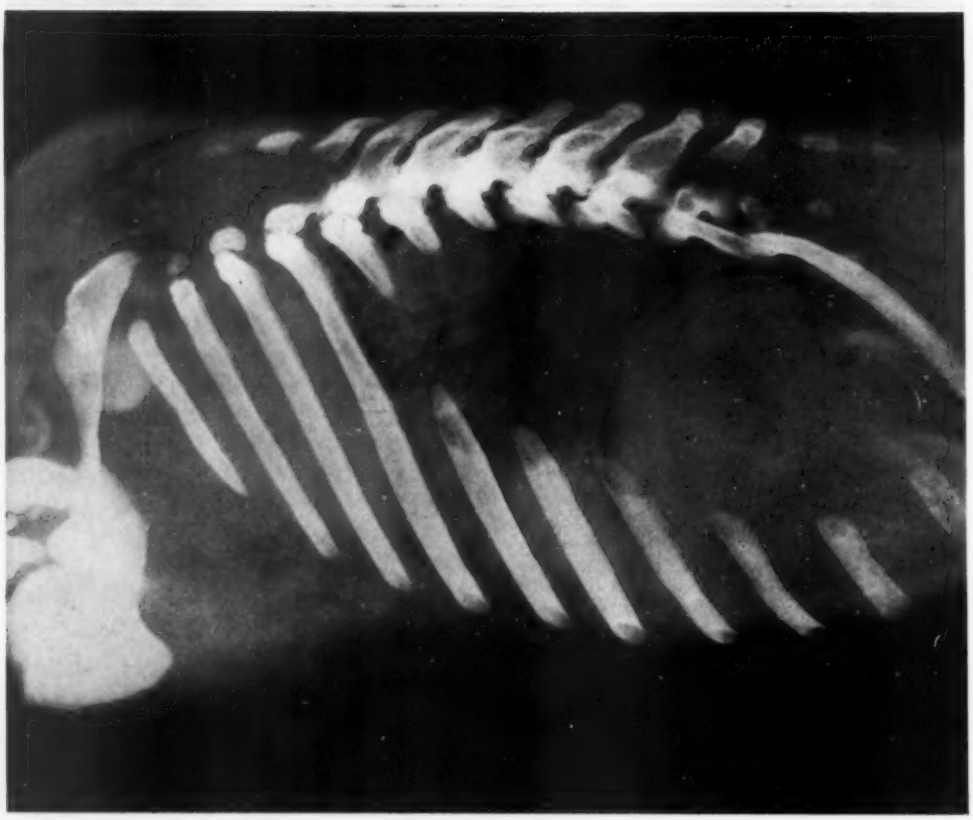

Fig. 13*a*. Roentgenogram of section v, left anterior oblique projection.

nation by lobes and portions of lobes would seem the more practical.

The bronchographic study of an entire lung at one examination, and of the contralateral lung at a second, is preferable to the injection of a portion of either or both at one time.

The *trachea* descends posterior to the fork formed by the innominate artery and the left common carotid and subclavian, as shown above, to divide into the right and left (stem) bronchi immediately posterior to or below the horizontal portion of the arch of the aorta and to the right of the bifurcation of the pulmonary artery. In its passage dorsal to the horizontal aorta, the trachea in the adult commonly pursues a slight arc to the right. The carina tracheae usually is to be seen at the level of the fifth or sixth thoracic vertebral body.

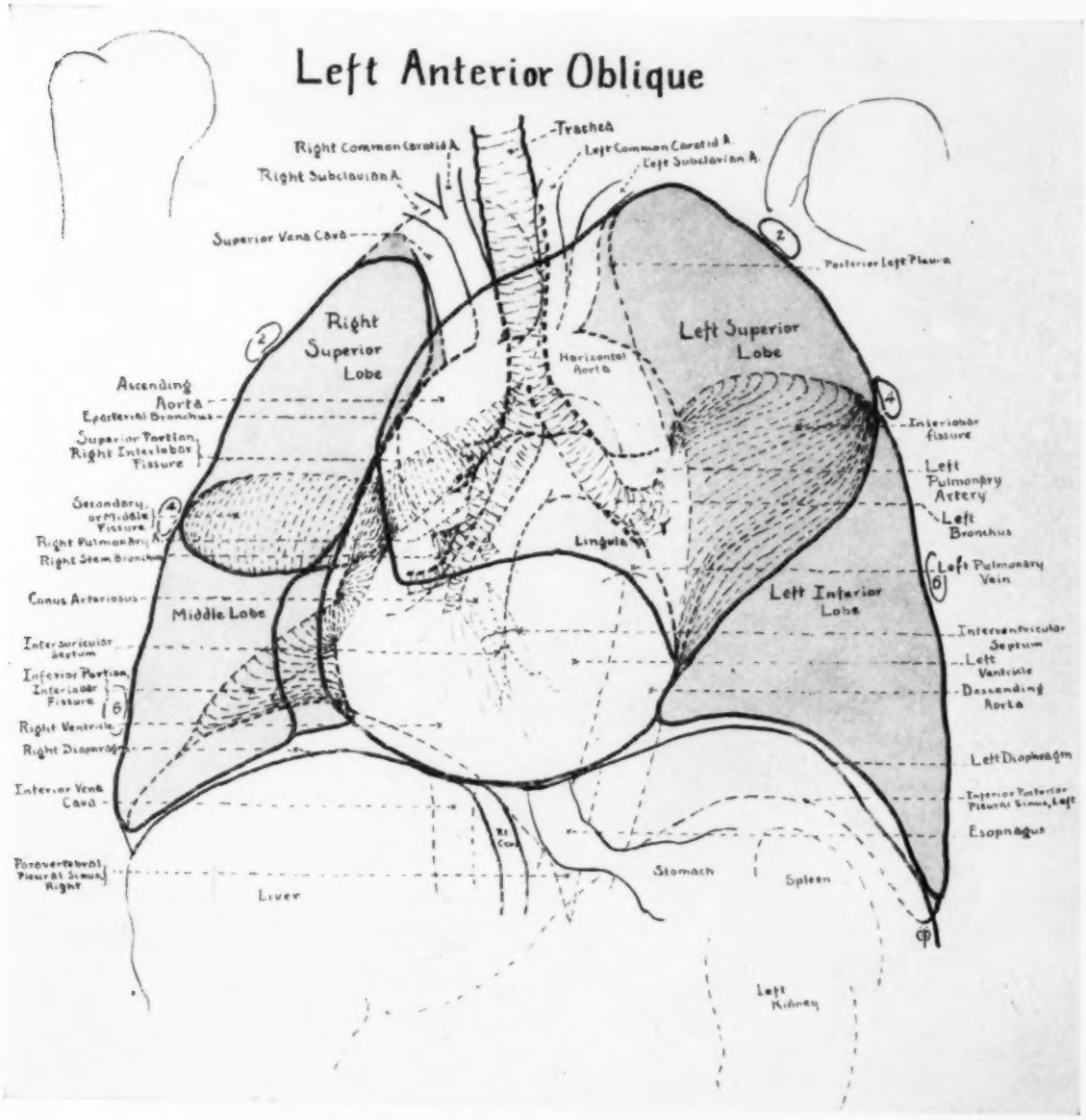

Fig. 14. Composite diagram of the structures to be visualized in the left anterior oblique projection of the thorax, based on Figures 9*a*–13*b*, inclusive.

Right Bronchus. Within the first 2 cm. the *eparterial bronchus* leaves the anterolateral wall of the right stem bronchus at nearly a right angle, to divide into three rami, an *apical*, a *dorsal*, and a *ventral*.

The *apical ramus* supplies the apical segment of the right superior lobe above the second rib anteriorly or the third rib posteriorly between the mediastinal surface and the axilla.

Fig. 15. Bronchogram (bilateral) of normal lung (371182) in frontal projection. Observe superimposition of major bronchi on each side.

The *dorsal ramus*, which may arise as a branch of the apical, supplies the inferior dorsal and posterior axillary portions of the superior lobe.

The *ventral*, or *axillary ramus* supplies the ventral, inferior mesial and anterior axillary remainder of the lobe. This bronchus and its branches are predominantly horizontal in position, overlying each other in the anterior lung field. The mesial tertiary bronchus particularly curves lateralward, ventralward and then mesialward over the others.

The oblique projection will separate these major rami from each other as they arise in a compact mass in the same sagittal and frontal planes.

The *middle lobe bronchus* (Figs. 16 and 18*b*) forms the first ventral branch of the "hyparterial" portion of the right stem bronchus arising from the anterior surface about 2 cm. below the eparterial and posteroinferior to the right pulmonary artery. It extends ventralward, lateralward and downward, dividing into three major rami supplying respectively the mesial, the ventral and the axillary portions of the middle lobe. Its axis and the distribution of its rami require projection in lateral or oblique planes to separate it from the branches of the dorsal lobe bronchus.

A *dorsal branch* of the right hyparterial bronchus (Figs. 16*a* and 16*b*) arises from the dorsal surface in the immediate vicinity of the middle lobe bronchus to supply the apex of the inferior or dorsal lobe above that level. In the frontal projection (Fig. 15), it is normally obscured by the middle lobe bronchus. In the lateral projection it may be visible but overshadowed by the cardiovascular mass and vertebrae. In the left anterior oblique projection it should be readily differentiated.

The remainder of the *right hyparterial bronchus*, continuing the axis of the trachea, divides shortly into three rami supplying the *ventral*, the *lateral* or *axillary* and the *dorsal basilar* (or inferior) portions of the inferior lobe (Figs. 16*a* and 16*b*). These have a similar axis in the frontal plane and must be projected obliquely to be adequately separated from each other.

A small *cardiac* branch has been described in the vicinity of the dorsal bronchus. This is commonly the mesial inferior branch of the dorsal hyparterial bronchus supplying the mesial portion of the inferior lobe.

The distribution of the bronchi on the right, therefore, carries out the rule of three, with its major divisions being the eparterial, the middle, and the hyparterial or inferior lobe bronchi, each in turn dividing into three, with the exception of the

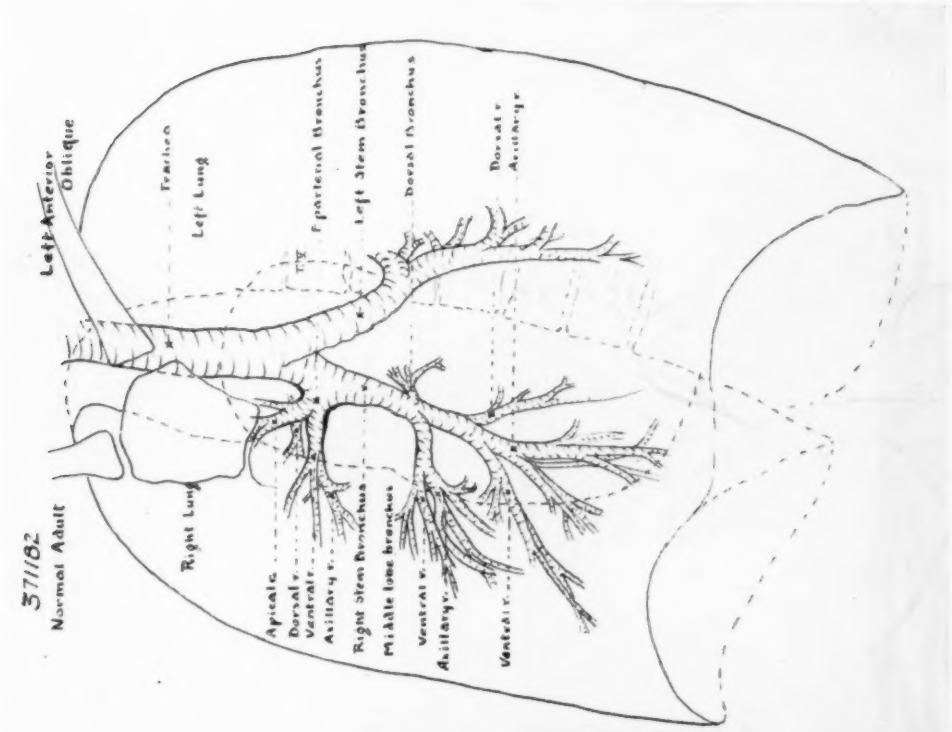

Fig. 16b. Diagram of the structures shown in Figure 16a.

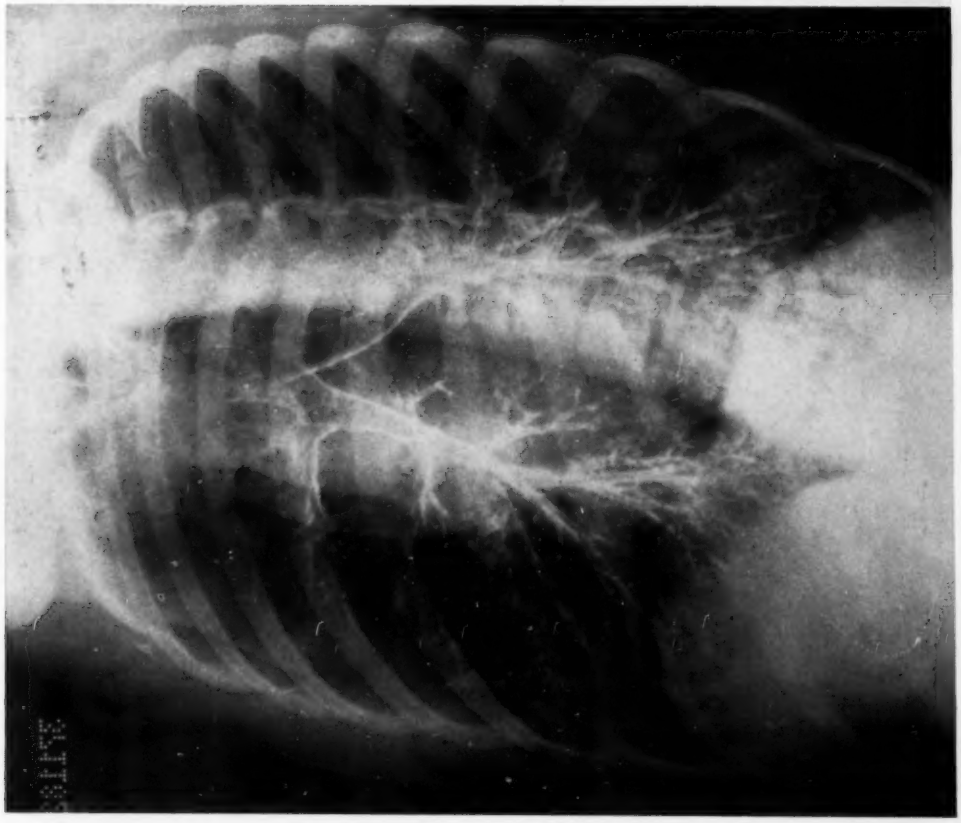

Fig. 16a. Same patient as in Figure 15 in the left anterior oblique projection, demonstrating the *right bronchial tree* in detail.

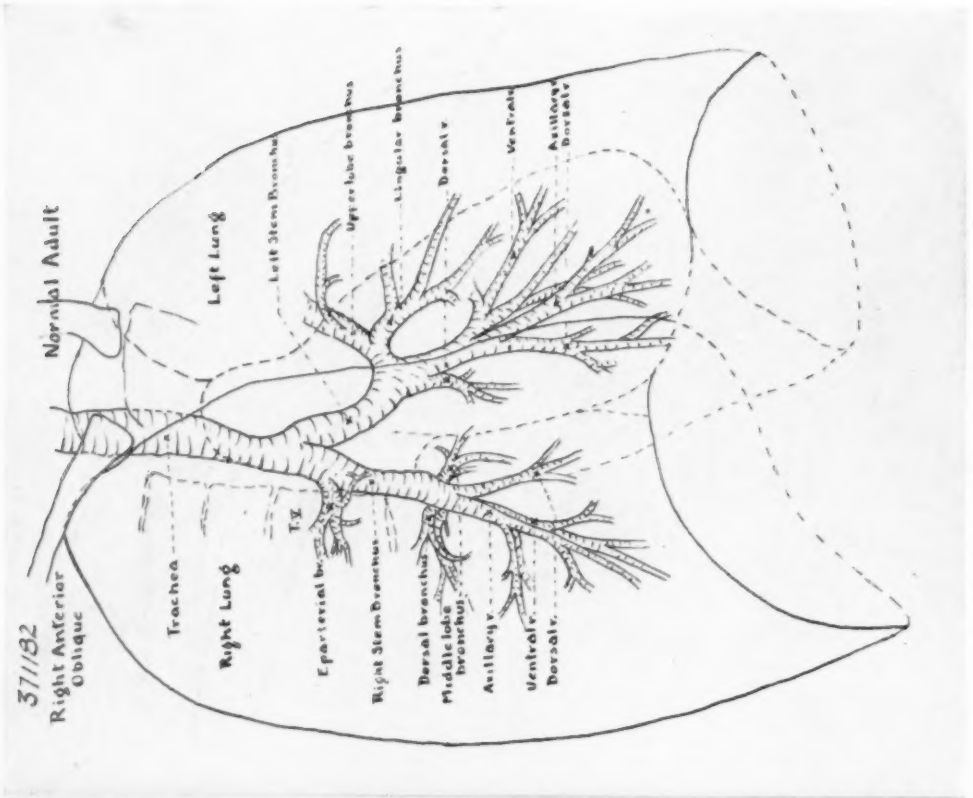

Fig. 17*b*. Diagram of the structures shown in Figure 17*a*.

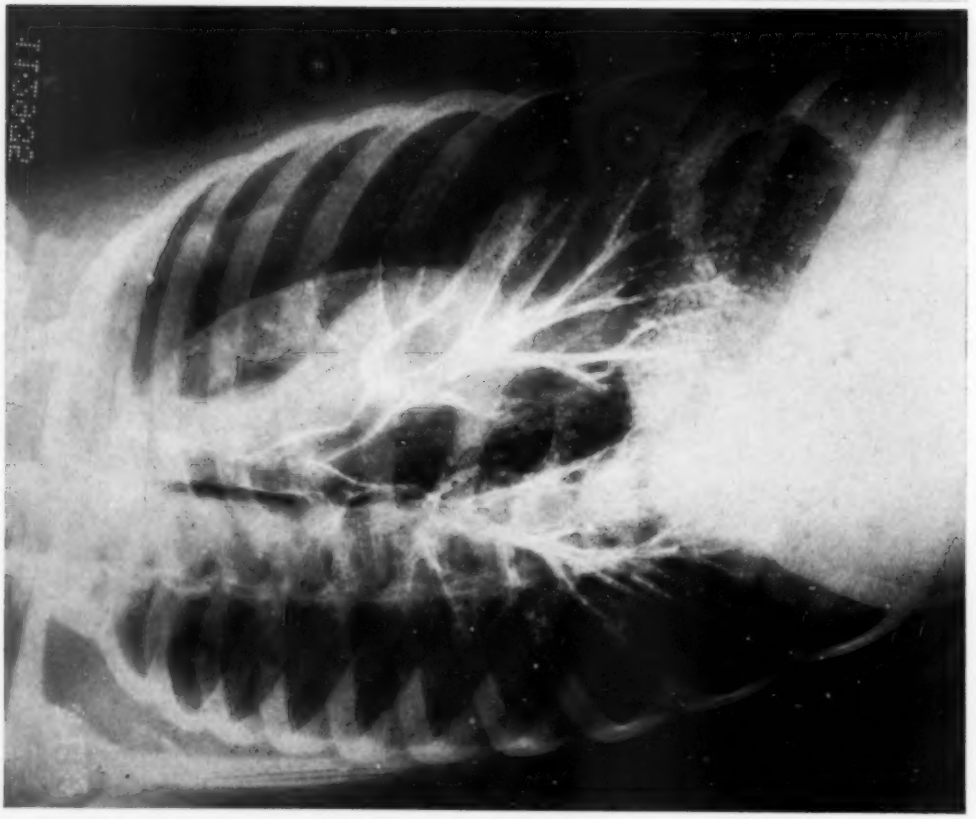

Fig. 17*a*. Same patient as in Figures 15 and 16*a* in the right anterior oblique projection, demonstrating the *left bronchial tree* in detail. Observe overlapping of right anterior and left posterior bronchi in the bilateral bronchogram.

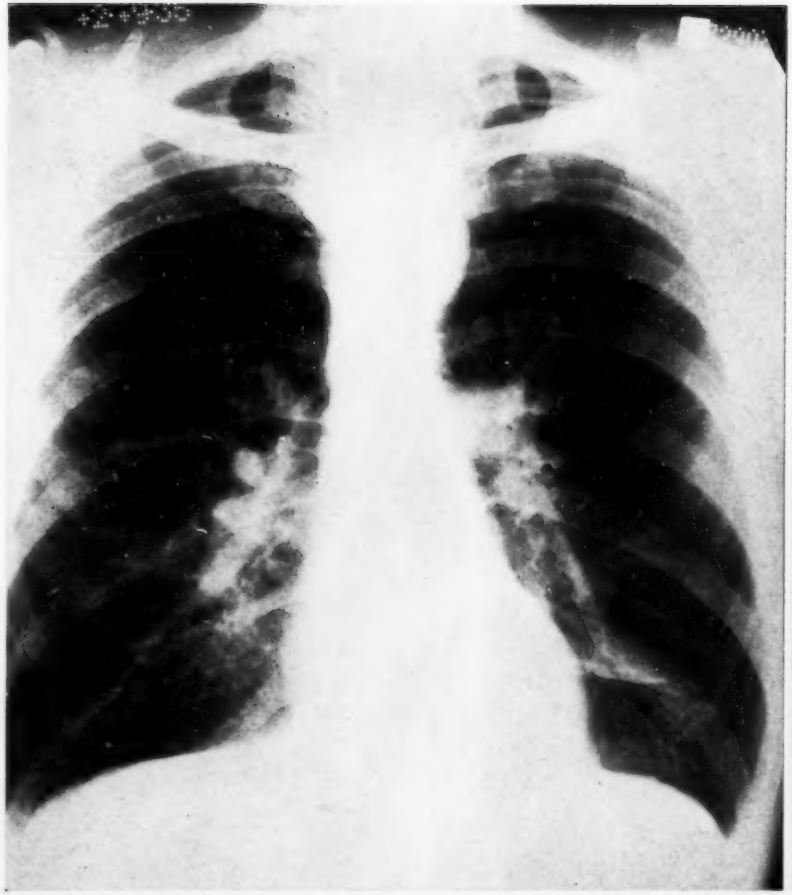

FIG. 18*a*. Frontal roentgenogram of healthy chest (329073) showing the optical sections of the *right pulmonary arteries* and the prominence of the left pulmonary artery at its division.

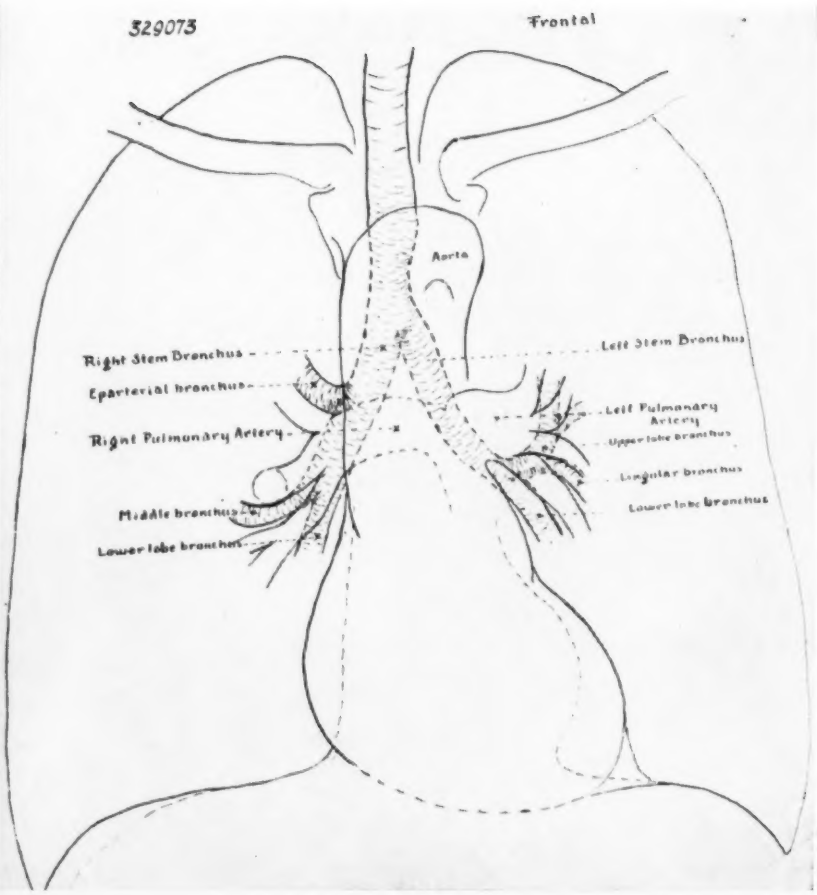

FIG. 18*b*. Diagram of the structures shown in Figure 18*a*.

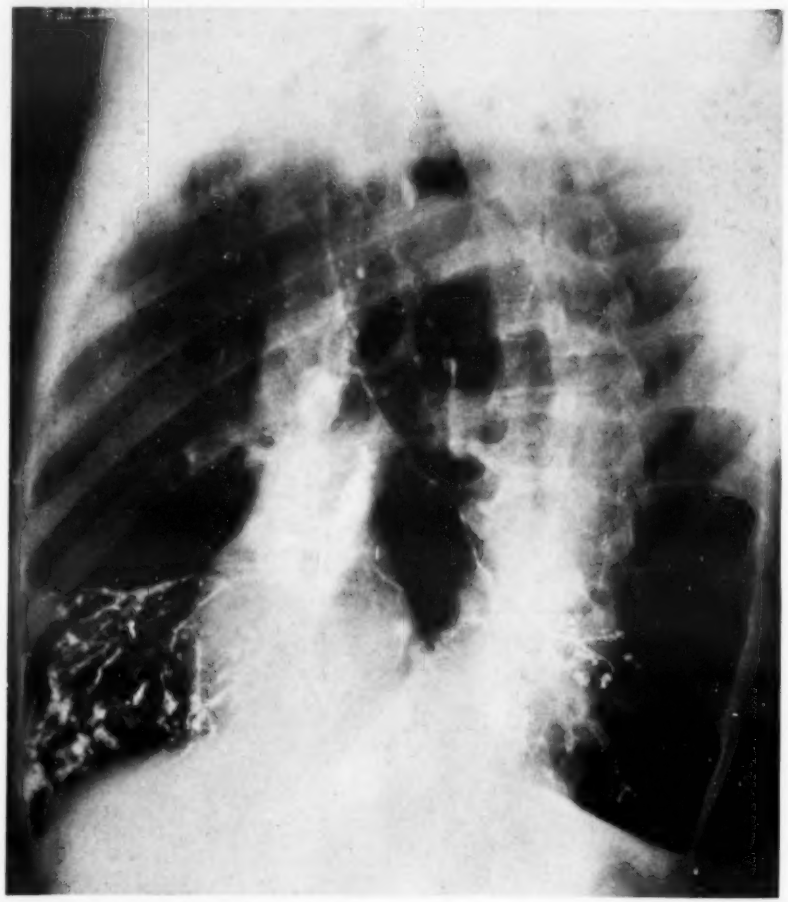

FIG. 19*a*. Left anterior oblique projection (of same patient as in Figure 18*a*), showing especially the relationship of the *left pulmonary artery* and the *left stem bronchus*. There is a bullous emphysema in the left inferior lobe.

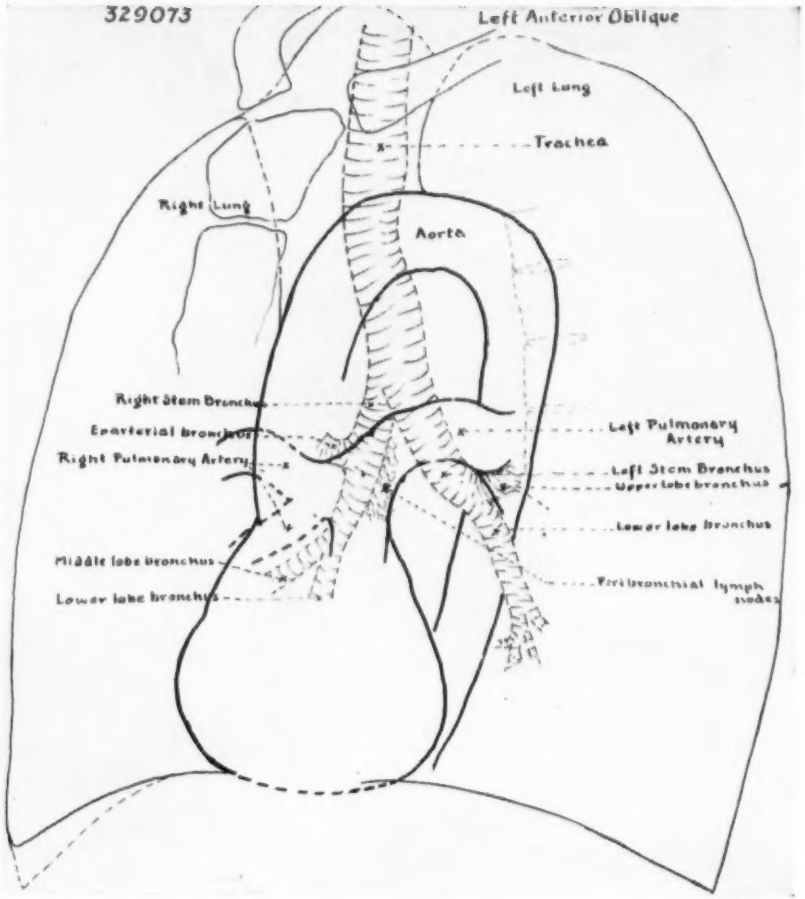

FIG. 19*b*. Diagram of the structures shown in Figure 19*a*.

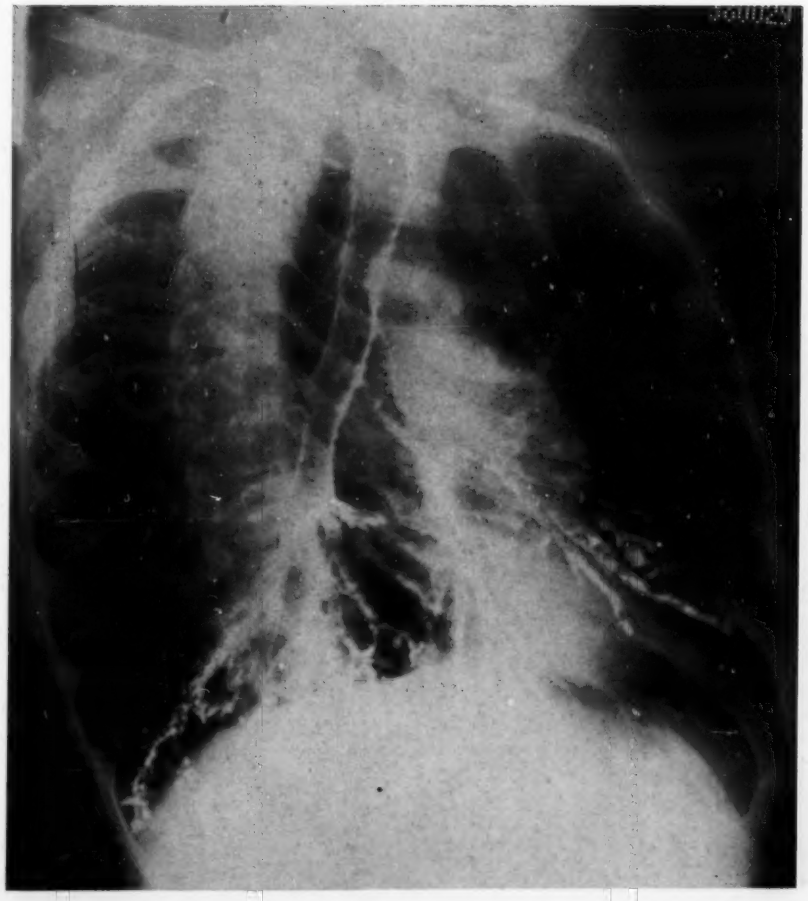

FIG. 20*a*. Right anterior oblique projection of another patient (380029) demonstrating especially the prominence of the *pulmonary conus* and *pulmonary artery* in this projection. This is within the limits of normal variation.

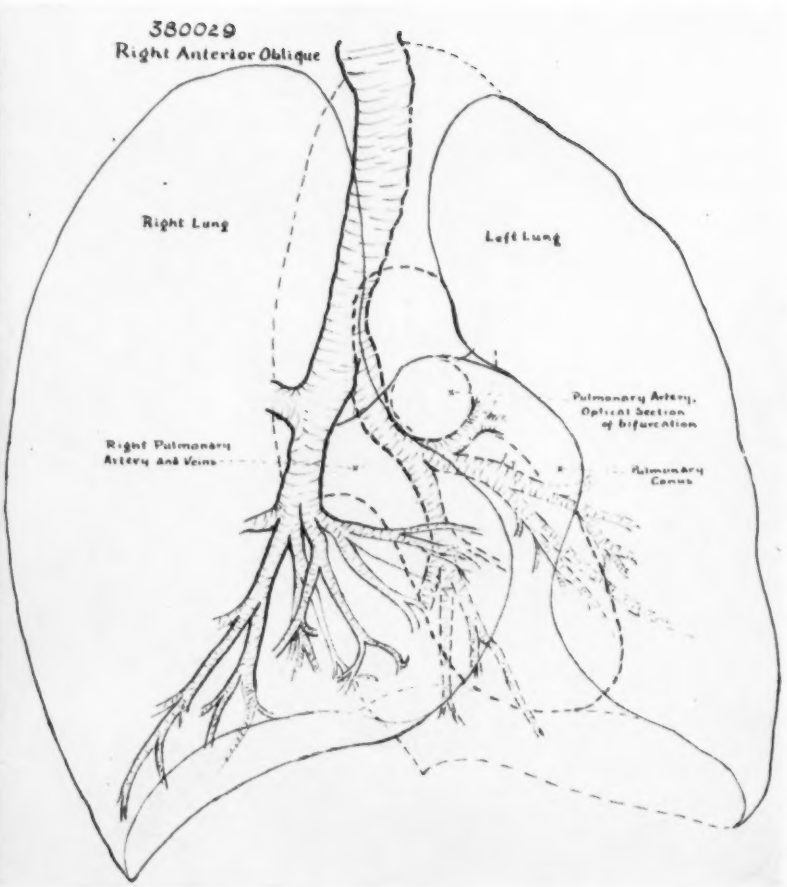

FIG. 20*b*. Diagram of the structures shown in Figure 20*a*.

dorsal bronchus for the apex of the inferior lobe.

The terms "ventral" or "dorsal hyparterial" rami seem confusing, as compared with the nomenclature used above.

Left Bronchus. The *left stem bronchus* continues the arc of the trachea posterior to the horizontal segment of the aortic arch, passing beneath the arch, posterior to the right pulmonary artery and under the bifurcation of the pulmonary artery (Figs. 17*a*, 17*b*, and 19*b*). There it divides, normally, into two major branches, the *superior* and the *inferior left bronchi* (both called "hyparterial").

The superior left bronchus (Figs. 17*b* and 19*b*) curves beneath and posterior to the left pulmonary artery to ascend slightly and there divide into an *apical*, an *axillary*, and a *lingular bronchus*. The dorsal ramus on the left more commonly arises from the apical bronchus than on the right. The distribution of the apical, dorsal and axillary rami is similar to that described for the right superior lobe, save that the axillary supplies the ventral portion of the lobe down to about the fourth rib.

The *lingular* ("ventral hyparterial" or left middle) *bronchus* is an analogue of the middle lobe bronchus of the right lung (Figs. 17*a*, 17*b* and 20*a*). It may arise independently from the stem bronchus. In such instances there may be a complete fission of this ventrolateral portion from the left superior lobe to form an accessory lobe. The lingula of the left superior lobe partially envelops the left heart and occupies the left anterior, inferior axillary portion of the thorax (Figs. 8 and 14). This is of particular importance in thoracic disease, in that it is commonly involved with the inferior lobe in bronchiectasis, without involvement of the superior portion of the left upper or ventral lobe. Therefore, it becomes necessary to adequately visualize this area and its bronchus, which may be accomplished best in the right anterior oblique projection.

The *inferior*, or "dorsal hyparterial" primary *bronchus* (Figs. 17*a* and 17*b*), is overlaid by the descending branches of the left pulmonary artery and the left heart for some distance. In that segment it gives off a *dorsal ramus* to supply the apex of the inferior lobe, as on the right. Its further division produces a triad of *inferior ventral* (or "basilar"), *axillary* and *dorsal rami* as in the contralateral lung. As on the right, the axis of these major rami, and in addition the overlying cardiovascular structures, permit adequate differentiation only in the oblique plane, preferably the right anterior.

Pulmonary Artery. The *pulmonary artery*, arising from the pulmonary conus on the anterior surface of the heart, passes upward over the origin of the aorta, to bifurcate on the left of the midline, anterior to and above the left stem bronchus (Figs. 14 and 20*b*). The rather sharp posterior arc of the pulmonary artery at the bifurcation, together with its position to the left of the ascending aorta and in the plane of the left margin of the sternum, presents an eminence in the left cardiovascular contour commonly called the pulmonary conus. This is incorrect, the pulmonary conus (*conus arteriosus*) lying in the anterior wall of the right ventricle at the origin of the pulmonary artery.

Because of this position of the bifurcation of the pulmonary artery on the left of the midline, and the dorsal distribution of the major branches of the *left pulmonary artery*, arising anterior to and above the left superior lobe bronchus, an optical section of the left pulmonary artery, commonly visible in the frontal plane at the root of the lung, is frequently erroneously interpreted as peribronchial hilar adenopathy (Fig. 18*a*).

The *right pulmonary artery* leaves the bifurcation at nearly a right angle passing posterior to the ascending aorta and anterior to the right stem bronchus and the right pulmonary veins, to divide into its several branches near the posterodextral margin of the ascending aorta.

With the exception of the branch to the right superior lobe, the rami of the right

and the left pulmonary arteries lie anterior and superior to their respective branches of the bronchi. The branch of the right pulmonary artery to the right superior lobe ascends from below and to the right of the eparterial bronchus.

Because of this distribution of the pulmonary arteries and the well-known density of optical sections of vessels, these structures are often wrongly considered peribronchial adenopathy. Further, it is well known that the major density of the "bronchovascular tree," which composes the lung markings, is the shadow of these arteries as they accompany the bronchi.

The left anterior oblique projection affords the best visibility of the left pulmonary artery, the right anterior oblique the maximum visibility of the pulmonary artery and its right main branch, with an optical section of the left main branch.

An optical section of both right and left pulmonary arteries is commonly visible anterior to the bifurcation of the trachea in the lateral plane. The right pulmonary artery is occasionally visible descending from this area, posteriorly.

SUMMARY

The roentgen anatomy of the right and left anterior oblique projections of the thorax has been demonstrated by means of roentgenograms of sections of frozen cadavers in corresponding planes.

The oblique projections of the thorax are especially advantageous in the demonstration of the bronchial tree and the pulmonary artery.

In bronchographic studies, the injection of the bronchial tree of one entire lung at one time, with the subsequent injection of the contralateral lung at another time, is suggested.

Attention has been called to the prominence of the pulmonary arteries, and the common misinterpretation of these normal structures as adenopathy at the roots of the lungs.

We wish to acknowledge with appreciation our indebtedness to Professor Rollo E. McCotter and Doctor Russell T. Woodburne, of the Department of Anatomy, University of Michigan, for their assistance in the preparation of the anatomic material and the identification of structures, and to Mr. C. R. Burd for the photographic reproductions.

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ROENTGENOLOGIC OBSERVATIONS ON THE RESECTED STOMACH FOLLOWING SURGICAL INTERVENTION

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ROENTGENOLOGIC research has been a great stimulus to the already numerous studies of the stomach operated upon by means of resection or gastroenterostomy, confirming, clarifying and often modifying to an essential degree the criteria deduced from clinical examinations and experiments upon animals.

The intensity and interest of such inquiries are increased in proportion to the progress of operative technique, which is continually reducing the limitations imposed by nature. In fact, it appears necessary to physiologists to exercise a certain control over the achievements of surgeons, and among the many operative methods proposed, to indicate those most likely to guarantee not only the anatomical recovery of the damaged organ, but also the maintaining of the functions of this organ in as nearly normal a manner as possible.

Roentgenology, therefore, offers the safest and the most suitable means for studying the operated stomach. The numerous roentgen observations which have been made were always followed from a few weeks to several months after the intervention in order to follow the organ in its gradual process of anatomical modification and functional adaptation.

So far as I am able to ascertain, the only study up to the present time, which refers to the roentgen observations made in abdominal operations beginning shortly after the surgical intervention until a satisfactory gastrointestinal functioning has been established, is the work by Prof. Cocci,[1] a surgeon in this hospital. This study had as its principal object the determination as to whether and up to what point, the physiology of the stomach was changed with regard to the tone, the peristalsis and the time of evacuation, following abdominal operations. On the basis of these observations it would have been possible to affirm or deny a direct influence of the gastric functioning on the cause of vomiting, which is so frequent whatever kind of anesthesia is used, whether general or local, and which is generally attributed to various reasons (anesthetic, postoperative acidity, irritation of the peritoneum, circulatory cerebral disturbances, etc.).

In his study, Cocci administered a suspension of 150 grams of barium sulphate in 200 c.c. of water. The examination was begun the day following the operation, and repeated daily until the stomach was empty of the greater part of the opaque fluid. The roentgen examination was made to establish the duration of the abnormal retention of barium in the stomach and correlate it with the operative findings and the condition of the patient.

The inquiry was afterwards extended also to sufferers of acute abdominal affections who had not been treated surgically. It is not my intention, however, to take these into consideration, as they do not concern the object which I have in view in this preliminary report.

Limiting myself, therefore, only to those abdominal cases which were operated upon and which total 36, I summarize briefly the conclusions reached by Cocci:

(1) Abnormal gastric retention of the barium is always verified after laparotomy. As a rule, there is complete gastric retention for the first

[1] Cocci, G. Osservazioni radiologiche sul funzionamento dello stomaco in operati ed in ammalati di affezioni addominali acute. *Prat. chir.*, 1930, *2*, 258–296.

twenty-four hours, but it may be protracted to a noticeable degree for two days. The longest retentions are generally observed after the most serious abdominal interventions (in the case of a subject operated on by gastric resection the stomach contained almost all the barium after six days). The retention is greatest in cases of laparotomy with drainage.

(2) In cases of vomiting, even when it is insistent, the barium is never, or only to a very small extent, expelled with the vomitus, and the gastric retention does not differ, either in existence or in length of time, from that generally observed when there is no vomiting.

A partial retention is often noted also in subjects to whom liquid food in fair quantity has been administered for some days, without the occurrence of vomiting or any other signs of intolerance to such nourishment. This is to be observed also when feces and gases are freely expelled. Instead, so long as the gastric retention is totally liquid, nourishment cannot be tolerated at all: the opening of the stoma then never precedes that of the pylorus. According to the difference in behavior, Cocci concludes that a total retention implies the absolute closure of the pylorus, while a partial retention may coexist with an active renewal of the gastric functions. In such cases, the persistence of the retention may be determined by a process of sedimentation of the barium, favored at first by the relative immobility of the subject, and by the supine position, and afterwards by the presence of a solid mass which adheres closely to the very irregular surface of the gastric mucosa, and which—as with all solid foods—is retained longer in the stomach than liquids. Moreover, on account of the law of gravity, such sedimentation takes place in the fundus, in a place in which not even in normal anatomical and physiological conditions are perceptible peristaltic waves produced, and where, on the other hand, the passive movements impressed by the diaphragm are feeble, and therefore inefficient as the reflex pain renders the respiratory movements superficial.

Therefore every mechanical factor which may favor the passage of the opaque bolus toward the pyloric antrum is lacking.

(3) In abdominal subjects a state of "gastric spasm," more or less accentuated and persistent, is constantly observed, according to the pre-existing grade of tonicity of the musculature of the stomach, the severity of the peritoneal irritation caused by the intervention, and—in part—to the quality and quantity of the anesthetic used.

The existence of this spasm, deduced from the roentgenoscopic image of the retention, is confirmed by the fact that if the patient is put on his feet the barium remains in a mass at the fundus of the stomach. And how can this fact so contrary to the laws of gravity, be explained except by admitting a state of valid muscular contraction, capable of straightening the passage between the walls of the stomach, thus impeding the descent of the heavy salt? Also in those cases in which the spasm yielded in part to the force of gravity, gastric hypertonicity was always clearly manifested.

From observations made at the time of the ingestion of the barium, Cocci maintains that the spasm takes place gradually during the hours following surgical intervention, i.e., when the effects of the narcotics are lessening. This view is in opposition to the importance attributed by many authors to the influence of drugs on the production of the postoperative gastric spasm.

Finally, Cocci, having constantly observed the presence of gastrospasm but never the passing of this to gastroplegia, asks whether those phenomena which are attributed to postoperative gastroplegia, and perhaps also the distention of the abdomen in abdominal cases, which are generally attributed to intestinal paralysis, may not be due to reflex spasms localized in those regions of the gastrointestinal tract in which the musculature is particularly strong. From the demonstration of this spastic condition the author makes useful suggestions for postoperative treatment. In fact he warns against the administration of all liquids during the days immediately following the operation; he then gives the preference to warm liquids and external hot applications, because spasms are notably favored by ice. He maintains that the administration of opiates is dangerous on account of their spastic action, and states that these should be made use of only with the utmost parsimony, or associated with other remedies of an opposite action, such as atropine.

Having thus summarized the principal observations and the most noteworthy conclusions contained in this work of Cocci's, which at the present time is considered

authoritative, and which deserves to be known for its intrinsic value as well as for the vast possibilities for study which it suggests, I ask why, among so many investigators who have studied the stomach roentgenologically, none—either before or after the encouraging example offered by Cocci—has thought or believed it opportune to extend their researches to the days immediately following the intervention. I say "thought or believed it opportune," advisedly, since it cannot be possible that no one has at least briefly considered this idea, but I am inclined to think that the jealous regard of the surgeon for his operated patient has prevented the roentgenologist from putting such ideas into action, and this, even when the surgeon and radiologist are one and the same person.

I, myself, after having assisted for several years in the operating ward, and having acquired a creditable knowledge of surgical cases, perhaps would not have overcome the fear of doing harm to my patients by the unusual treatment to which I should have to subject them, had I lacked first the example, and then the encouragement and continual assistance of Professor Cocci. The earliest observations, however, were carried out with the utmost caution, only once a day and for a very short time which allowed of only a rapid roentgenoscopic examination, after ingestion of a small quantity of barium, and, as Cocci had already done, even then with the patient only in the supine position, thus maintaining almost complete immobility of the subject. The absolute harmlessness of these first attempts strengthened my assurance and induced me to gradually improve the conditions of the examination (in this I also followed the excellent advice given me by Professor Siciliano), until I thought it sufficient, for the purpose of my research, to use the following plan:

(1) Twenty-four hours after surgical intervention, gastric lavage by means of a nasal stomach tube, completely removing the contents of the stomach (residual operative blood, products of secretion). Afterwards, under roentgenoscopic control, slow ingestion of an average of 100–150 c.c. of an aqueous suspension of neobarium (salt 1 part, water 3 parts). Roentgenoscopic observation for ten to twenty minutes of the behavior of the stomach; then roentgenographic confirmation.

At first, i.e., during the process of filling the stomach, the roentgenoscopic examination was performed with the patient in the supine position and then in the prone position. Roentgenograms were taken in both these positions.

(2) After thirty-six hours (time is always calculated from the moment of surgical intervention) the roentgenoscopic and roentgenographic observations were repeated, followed by a gastric lavage, always by means of a nasal stomach tube, with removal of almost all of the barium, this being done in order to avoid, or at least to reduce as far as possible, the sedimentation of the opaque salt, which might affect the subsequent observations. Finally a fresh ingestion of an equal quantity of neobarium was given with the patient in the supine position.

Prolonged roentgenoscopic observations were made with the subject in the supine, prone, and standing positions. Roentgenograms were taken with the patient in all these positions.

(3) After forty-eight hours, roentgenoscopic and roentgenographic examinations in the same three positions. Gastric lavage. Similar administration of the opaque liquid, first in the prone position, then also standing before the roentgenoscope. Roentgenoscopy, roentgenography.

The examination was repeated every twelve hours in identically the same manner, until a gastric function which permitted the subject being regularly fed with liquids had been established.

This procedure was applied to 14 cases with the consent of the patients and with no discomfort to any of them. In those operated upon for gastric disorders and treated in this manner, vomiting was

always absent, and in every instance the troublesome sensation of gastric burning and acidity which is often complained of, even when the postoperative course is ideal, was lacking.

In this preliminary report I shall limit myself to those observations obtained in operations for gastric or duodenal ulcer, or for both. Those operated upon for carcinoma are, of course, excluded, as in these cases the patients are no longer young and their general condition is somewhat precarious, so that resection is usually more far reaching and therefore the likelihood of postoperative complications (hemorrhage, imperfect holding of the suture) is greater. In the cases studied, young subjects in good mental and physical condition and on whom the operation was successful, were chosen. Thin persons were used so that changes in position could more readily be made without discomfort.

The operation used was that of Finsterer-Hofmeister, i.e., lower gastrojejunal anastomosis, in which the anastomosis with the jejunum is limited to the lower part of the gastric section, while the upper part is without an outlet. The stomach is sectioned obliquely in respect to its major axis, and parallel to the median axis of the body. The anastomosed jejunal loop has a very short afferent end and an efferent one passing almost vertically downward.

The operation was performed under local anesthesia, with novocaine, and a previous general anesthesia with H. M. C. or paunevrol; only in a few cases was it necessary to make use of general ether anesthesia. In all cases at the beginning of the roentgen examination the effects of the various anesthetics used could be considered insignificant.

Having thus briefly indicated the condition of the subjects, and the method of examination, I shall now give a detailed report of 3 cases which sum up and point out the variations observed.

REPORT OF CASES

Case 1. Rosa C., aged forty-seven. Clinical diagnosis of secondary pyloric stenosis. The roentgen examination showed marked gastric ptosis and ectasia; peristalsis rather weak with superficial and rare undulations. The pylorus remained closed for the first half hour, followed by the evacuation, which proceeded very slowly. There was a small niche, not very painful, on the lower contour of the pyloric ring; the duodenal bulb showed a greatly reduced shadow. Nothing noteworthy was seen in connection with the intestines. Therefore the diagnosis of a cicatricial stenosing pyloric ulcer was confirmed.

After a few days' preparation with gastric lavage, the operation was performed. The following are the notes taken at the operation:

General anesthesia with H.M.C.; local anesthesia with 0.5 per cent novocaine. Median laparotomy. There is a very hard cicatrized area which occupies the first portion of the duodenum and the pyloric ring, adhering to the liver, from which it had to be detached. Gastrectomy for the excision of three-fourths of the stomach. The section of the duodenum falls at the upper limit of the cicatrized area, which is only partially extirpated. Finsterer-Hofmeister reconstruction. The patient recovered consciousness rapidly, and an hour after the termination of the operation she replied with perfect lucidity to the questions asked her. No sign of vomiting.

Twelve hours after the operation, the time being calculated from the beginning of the operation, the general condition was most satisfactory in every respect. As usual, a gastric lavage was given by means of a nasal stomach tube, and on account of the perfect tolerance of the subject, almost the whole of the gastric contents was removed.

The following morning, i.e., twenty-four hours after the operation, the condition of the patient was excellent since she had suffered neither retching nor hiccoughs, and had had a quiet night. Having checked the blood pressure, the pulse, which was 90, the temperature, 37.8°C., and the quantity of urine, which was normal, I considered it quite safe to proceed with the roentgen examination. Therefore the patient was conveyed to the diagnostic ward and placed carefully on the roentgenoscopic table. Here the lavage was repeated through the nasal tube until the stomach was emptied of all residuum. The absence of recent blood also reassured us concerning the eventual presence of those slight hemorrhages of the

FIG. 1*a*. Case 1. Twenty-four hours after surgical intervention. Roentgenogram taken in prone position sixty minutes after the forced opening of the stoma. There is little gastric residue; the walls of the stomach present incisures which are scarcely visible; the evacuation is nearly complete; the afferent jejunal loop shows slight traces of barium. The first jejunal coils beneath the anastomosis are well filled.

mucosa which are by no means rare, and which at times become so insidious. The opaque liquid was then administered under roentgenoscopic control, by means of the nasal stomach tube. After the first 50 c.c. the gastric stump was already visible in its entirety, showing good tonicity of the walls, and mucosal folds in high relief. The gradual introduction of the next 50 c.c. did not modify the result in any substantial way, but only showed with greater clearness the hypertonicity of the gastric stump, which began to assume in outline the pear shape with the apex at the bottom, which has been described as characteristic of the resected stomach, after the technique of Finsterer-Hofmeister.

The patient meanwhile remained calm, and even when questioned did not note any sensation of discomfort different from those already mentioned. I therefore continued, but with greater caution, to administer the liquid, and only when I had given 130 c.c. was there observed a sudden eruption of the opaque liquid in the efferent jejunal loop, while slight traces, scarcely visible, passed into the afferent loop.

The stoma remained completely open as long as the ingestion of the barium continued (producing some eructation and a sense of gastric distention), and closed completely when the ingestion of barium ceased. After only a few minutes the barium remained quietly in the stomach and in the first loop of the jejunum, and in the roentgenograms it is possible to recognize the anastomotic jejunal loop compressed and almost crushed against the line of suture (Fig. 1*a*). During this examination, which lasted altogether for forty minutes, three roentgenograms were taken, at intervals, one in supine and two in prone position, after which the patient was taken back to bed.

Since the subjective condition of the patient, the state of the heart and of the abdomen remained excellent, after thirty-six hours I made the second roentgen examination (Fig. 1*b*). The appearance of the stomach was exactly the same as that observed twelve hours previously. There were no traces of barium in the small intestines, which indicated that the anasto-

FIG. 1*b*. Case 1. Thirty-six hours after surgical intervention. Roentgenogram taken in prone position. The gastric residue presents the same appearance as that noted in the preceding examination, at the completion of evacuation (see Fig. 1*a*). The ascending colon and the cecum contain barium while there is none in the small intestines.

mosis had remained entirely closed except for the brief period during introduction of barium. I observed a small quantity of barium, corresponding to that which I had seen enter the jejunal loop, present in the cecum and the ascending colon.

The usual gastric lavage was done and the customary quantity of barium was given. The stomach and the anastomotic jejunal loop acted in exactly the same manner as they did at twenty-four hours, except that the stoma opened after the introduction of 100 c.c., and the walls of the stomach showed a greater tonicity.

After forty-eight hours. The gastric retention had not appreciably lessened; there was no trace of barium in the small intestines; the cecum, the ascending and the transverse colon were slightly filled, the descending colon somewhat more. From this it was concluded that while the stoma had remained closed, the first column of barium had entered the large intestine with normal rapidity.

Gastric lavage until the stomach was completely empty. Introduction of the barium through the nasal stomach tube. The same quantity of barium was necessary to force the opening of the stoma, but the evacuation was far more protracted, although with decreasing rhythm, so much so that it was still perceptible after thirty minutes. The stomach was hypertonic, and there appeared rather deep incisures, which, however, did not remain (Figs. 1*c* and 1*d*).

Fig. 1*c*. Case 1. Forty-eight hours after surgical intervention. Roentgenogram taken in prone position. The forced evacuation began a few minutes previously and many coils of the jejunum are already filled; the right colon and the transverse colon are not very well filled, while the left colon is well filled.

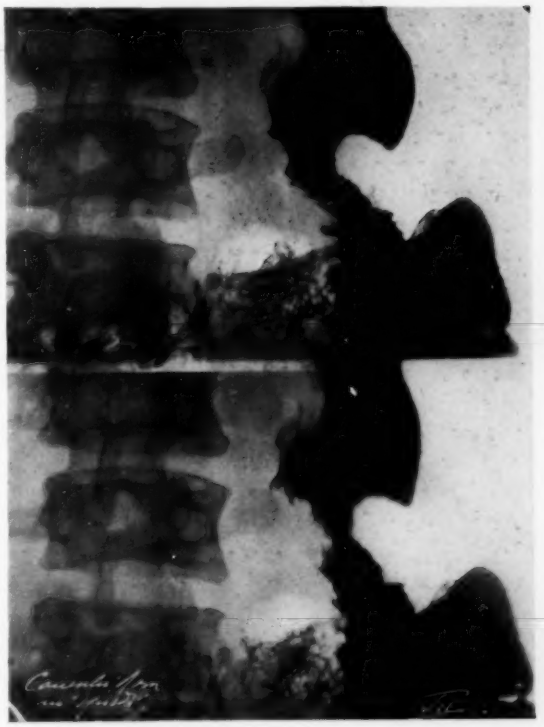

Fig. 1*d*. Case 1. Forty-eight hours after surgical intervention. Roentgenogram taken with the patient standing, with seriograph, ten minutes after Figure 1*c*. The gastric residue is greatly diminished; wide incisures are noted on the contours of the stomach; the breadth of the stoma is rapidly decreasing (compare Figs. 1*a* and 1*b*).

After sixty hours. Gastric residuum somewhat diminished; traces of barium in the small intestines. The whole of the colon was filled. The introduction of the opaque liquid, after previous gastric lavage, caused an opening sooner, more ample and longer lasting.

After seventy-two hours. Minimum gastric retention. The anastomosis opened immediately, and the evacuation of the barium administered took place with rapidity and without interruption. The stomach was hypertonic. The anastomotic jejunal loop was filled to a great extent in its efferent part.

During the morning the bowels moved.

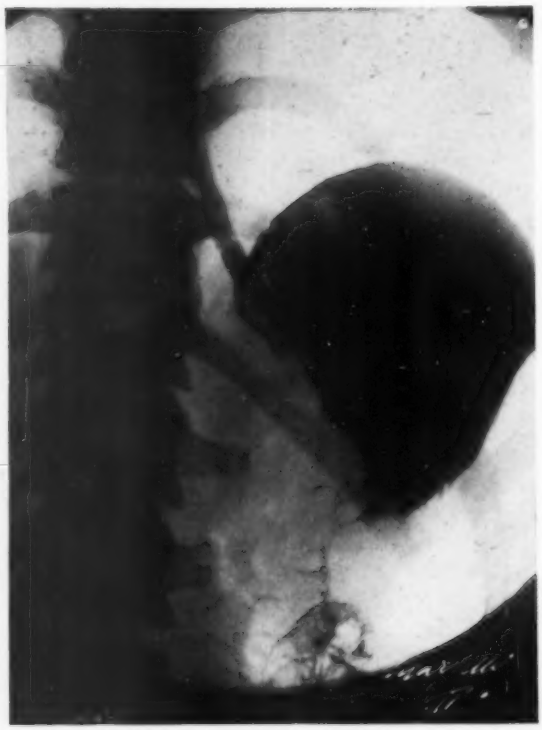

Fig. 2*a*. Case II. Twenty-four hours after surgical intervention. Roentgenogram taken in prone position. The stomach is distended, while only slight traces of barium have filtered across the anastomosis. It was necessary to suspend the introduction of barium and let it drain off externally, through the nasal stomach tube.

Liquid alimentation was begun and was perfectly tolerated.

Case II. Caesare M., aged thirty-eight. The anamnesis and the objective examination indicated a gastric ulcer. The roentgenoscopic examination showed "the stomach in normal position and hour-glass shaped on account of constant mediogastric constriction. In the narrow part, along the small curvature there was a penetrating niche which is very painful to pressure."

Operation was carried out with local anesthesia and ether to the closure of the stomach. The abdomen being opened by median laparotomy, a stellated cicatrix was observed on the front face of the duodenal bulb; a small lump was moreover felt on the middle part of the small curvature. Gastrectomy of three-fourths of the stomach and portion of duodenum. Finsterer-Hofmeister reconstruction. Under examination, the excised tissue showed the existence of an ulcer on the lesser curvature, the size of a grain of wheat, hollowed out and with thickened borders. In the duodenal bulb no ulcers were macroscopically visible.

The patient had a few attacks of vomiting about two hours later, which, however, ceased quickly and were not repeated.

After twelve hours. The subjective conditions were most satisfactory. With gastric lavage, a small quantity of dark blood and mucus was removed. During the night injections of pantopon were given.

After twenty-four hours. By gastric lavage the stomach was rapidly emptied of the last residues of the operation. No recent blood was noted. The patient was placed upon the roentgenoscopic table, and by means of a nasal stomach tube an aqueous neobarium suspension was given, in the aforementioned proportions. The stomach was observed to distend gradually, and was delineated in its entirety after the introduction of 70 c.c. of the liquid. The manner in which it filled and the aspect of

Fig. 2*b*. Case II. Thirty-six hours after surgical intervention. Roentgenogram taken in prone position. Stoma completely closed. No traces of barium in the small and large intestines. The crenation of the margins indicates the good tonicity of the gastric stump.

the margins clearly showed the good tonicity of the walls (Fig. 2*a*). The contracture of the stoma yielded only after a somewhat forced distention of the stomach (180 c.c.). The patient at this point complaining of an uncomfortable feeling of gastric fullness, the introduction was suspended, and a part of the barium allowed to drain off from the tube. This defluxion took place under considerable pressure, and while the stoma was completely closed. Only a small quantity of the opaque liquid therefore filtered into the jejunal loop.

After thirty-six hours. The postoperative course being excellent, a second examination was made. The aspect of the stomach was precisely the same as that observed twelve hours previously, after it had been partially emptied of the barium. In the small and large intestines no trace of barium could be seen, not even with roentgenography. This indicated that the anastomosis had been closed for several hours, and therefore probably since the preceding examination. The quantity of the opaque mixture that was previously observed in the efferent jejunal loop had become mixed with the abundant liquid contents of the small intestines, and so was no longer sufficiently opaque to the roentgen rays (Fig. 2*b*).

Therefore almost the whole of the gastric residuum was carried away by means of a lavage through the nasal tube.*

Following the introduction of the barium a behavior analogous to that observed during the morning was noted. When the stoma closed the jejunal loop was recognizable, very thin, with the wall opposed to the section applied against the suture line.

After forty-eight hours. The whole of the barium still lay stagnant in the stomach. Lavage and fresh introduction of barium showed evident hypertonicity of the gastric walls. The distention reached during the previous examination was not attained because the stoma opened with extreme rapidity (after 75 c.c.); the evacuation was greater and more prolonged, and rudimentary contractions were seen on the contour of the gastric stump.

After forty-five minutes, i.e., at the termination of these observations, the passing of the barium into the efferent jejunal loop still continued, although with a slower rhythm. The afferent loop was only just recognizable.

After sixty hours. The gastric stasis had greatly diminished; there was presence of barium in the lower loops of the small intestines, the cecum and the ascending and transverse colon. It was therefore thought that the gastric evacuation had been protracted for at least some hours after the last roentgen examination. The patient had a general feeling of wellbeing. Gastric lavage was performed, and then, standing, the patient was given a glass of neobarium. Under the roentgenoscope the stomach was seen to distend moderately, then contract, and then an intermittent evacuation began, with waves of contraction on the gastric stump, and pendulum movements of the ana-

Fig. 2*c*. Case II. Sixty hours after surgical intervention. Roentgenogram taken in prone position. Waves of superficial contraction of the gastric stump are seen. The relaxation of the stoma is not complete, as is proved by the moderate filling of the efferent jejunal loop. The afferent loop is not recognizable. (The roentgenoscopic observation showed that the evacuation was intermittent, not in torrents, and that the jejunal loop presented pendulum movements.)

* I would here note how in a case in which I wanted to omit such lavage, following throughout the various examinations the behavior of the barium administered at the beginning, I had the most ample proof of the stasis of the sedimentation that is held by Cocci. In this case, I found a considerable opaque residuum four days after the initiation of a sufficient liquid alimentation. To carry it away a prolonged lavage with the stomach pump under great pressure was necessary.

Fig. 3*a*. Case III. Twenty-four hours after surgical intervention. Roentgenogram taken in prone position. After the introduction of 50 c.c. of barium the stomach shows good tonicity of the walls; it is visible in toto; the stoma is closed.

stomatic jejunal loop. Roentgenograms were made with the patient prone (Fig. 2*c*).

At the next examination the functioning of the stomach was active and the evacuation took place in the whole canal, while the efferent loop showed a normal caliber.

Case III. Primo F., aged fourteen. Clinical and roentgenological diagnosis of duodenal ulcer. The patient presented signs of conspicuous hypertonicity and of parasympathetic hyperexcitability. Operation was performed on February 8, 1935. The following notes are copied from the register of operations. "Prenarcosis with H. M. C. Local anesthesia with novocaine 0.5 per cent. Median superumbilical laparotomy. Evident cicatricial retraction in the juxtapyloric region, extended and stellated. Resection of three-fourths of the stomach and portion of duodenum. Finsterer-Hofmeister reconstruction. The examination of excised tissue shows intense reddening of the duodenal mucosa which is sclerotic in the part corresponding to the retraction. In the lateral recess of the bulb an ulceration the size of a peppercorn is noted."

The postoperative course was ideal. Vomiting and hiccough were both absent; there was no sensation of burning or of acidity, only the frequent request for water.

After twelve hours. A gastric lavage was given with comfort, and this removed all residue of the operation. The gastric lavage—which appeared superfluous—was repeated on the roentgenoscopic table, following which the usual suspension of neobarium was given by means of a nasal stomach tube. The stomach was hypertonic, and after 40 c.c. it was outlined in its entirety. The quantity given was limited to 50 c.c. The stoma remained completely closed.

Roentgenoscopic observations were made with the patient prone and standing, and roentgenograms were taken (Fig. 3*a*).

After thirty-six hours (Fig. 3*b*). All of the barium remained in the stomach. The patient had only a slight fever, in keeping with the operative wound. After gastric lavage, barium was again administered. There was a feeling on our part that the stomach resisted far more to this distention than in the other cases,

Fig. 3*b*. Case III. Thirty-six hours after surgical intervention. Roentgenogram taken in prone position, previous to a new introduction of barium; total retention of the barium in the stomach.

therefore we did not consider it advisable to use more than 90 c.c., and upon the tube being opened the opaque liquid flowed away under strong pressure (it must be remembered that owing to the age of the subject the remaining portion of the gastric stump was far smaller). In this case the opening of the stoma was not effected.

After forty-eight hours, by nasal lavage, the barium which was withdrawn was mixed with a small quantity of bile, and on fresh introduction of barium, after 100 c.c., the liquid suddenly burst into the intestine. The first loop of the jejunum appeared completely dilated and the barium rapidly entered. A deep incisure was outlined on the large curvature of the gastric stump, from which a good tonicity of the walls was deduced. Evacuation proceeded even when the gastric contents were greatly reduced, i.e., when the factor of mechanical distention could no longer be admitted as the determining cause (Fig. 3*c*).

The opening of the stoma was not continuous but underwent short interruptions without rhythm. Forty-five minutes after the beginning, slight but definite evacuation of the stomach still continued.

After sixty hours, a small quantity of barium remained in the stomach. The last loops of the small intestines, the cecum and the ascending colon were visualized. Considering gastric lavage as superfluous, the neobarium was immediately given without the stomach tube, the patient standing before the roentgenoscope. The evacuation took place very soon, rapidly, in torrents, with the stoma completely relaxed. After a few moments there remained only the barium of the sedimentation in the gastric stump, which is normally tonic, and with the incisure of the large curvature higher and deeper.

It should be added that this subject was treated with daily injections of atropine, in view of the aforementioned state of hypertonicity and parasympathetic hyperexcitability.

The results of the researches in these 3 cases were repeated, with slight variations, in the remaining 11 observed by me, following the same manner of examination. It therefore appears that from the roentgenologic examinations the following general conclusions may be drawn:

Fig. 3*c*. Case III. Forty-eight hours after surgical intervention. Roentgenogram taken in prone position. The filling of the stoma indicates that the emptying is proceeding, although the gastric contents are less than in the preceding examination.

(1) During the hours immediately following the intervention:

(a) Remarkable tonicity of the walls of the gastric stump.

(b) Spastic closing of the stoma.

(c) Contracture of the anastomosed jejunal loop in correspondence with the anastomosis.

(d) Good canalization of the efferent loop and of the various portions of the small and large intestines.

The tonicity is demonstrated by the fact that during the introduction of the barium the stomach distends slowly but uniformly, becoming visible in toto even with a small quantity of opaque liquid. Moreover, during the introduction, as well as at the conclusion of the same, the contours of the stomach appear crenated, and the muscosal folds are also clearly visible, often far more accentuated than they normally are. The

opaque residuum retains its appearance even several hours after administration of the barium, i.e., after prolonged immobility with the patient in prone position (see roentgenograms of patient in prone position and standing).

The spastic closure of the stoma is demonstrated by the fact that this remains closed even when the stomach has reached a noteworthy distention, at times causing the patient suffering, to yield suddenly (as a necessary mechanism of defense) to an excessive filling, which also shows a further distention of the cardia, already penetrated by the stomach tube. That only this mechanical action determines the momentary resolution of the spasm can be further deduced from the fact that as soon as the overflow of the liquid has passed into the jejunum, the stoma again closes in a complete and characteristic manner.

The contracture of the anastomotic jejunal loop is clearly demonstrated. It is especially evident in the roentgenograms taken a few minutes after the closure of the neo-pylorus, when traces of barium are still adherent to the intestinal mucosa.

Finally, there is demonstrated that there exists, at least from the beginning of the second day, a free canalization of the intestine by the rapidity with which the barium, the stoma being forced, proceeds into the loop of the jejunum, and by the time employed by it to reach the sigmoid. (In the first case in which the opening of the stoma was induced twenty-four hours after the intervention, so much was retained that it allowed the passage of a sufficient quantity of barium into the intestine already twelve hours after the ascending colon was filled, and twenty-four hours after the descending colon.)

(2) During a second period from forty-eight to sixty to seventy-two hours after the intervention:

(a) The tonicity of the gastric stump increases sensibly in every case.

(b) The contracture of the stoma always becomes more pronounced until it yields completely (evacuation in torrents).

(c) The anastomotic jejunal loop presents a normal caliber.

(d) The progression of the barium in the intestine is increased by a greater strength of the movements which are peculiar to it.

Having given the roentgenologic findings of the cases which I have observed and the deductions which can be drawn from them, there still remains to be studied the genetic mechanism of the functional behavior of the resected stomach during the hours immediately following the intervention. In this study various groups of factors may be taken into consideration:

1. A mechanical action due to the edema of the tissues in the seat of the anastomosis, by local vascular congestion, and by the presence of small blood clots in the structure of the gastric and intestinal walls around the suture. Mechanical action coupled with the turgidity of the walls may result in a stricture of the stoma, and above all in diminished elasticity and greater resistance to separation of the two lips of the stoma.

2. A nervous reflex action on the gastric and intestinal muscular fibers, always in the vicinity of the stoma, due to the irritation of local traumatism, to the presence of the sutures, to the section of the nerve endings, to the presence of extravasated blood, etc. Reflex action which may be manifested by spasticity, or by contracture of the muscular fibers immediately adjacent to the stoma.

3. A reflex action, caused by the irritation of the abdominal peritoneum in the prolonged operative traumatism (the operation always takes about two hours), and which may be manifested in the above manner, but also distant from the stoma in the residual gastric stump and in the intestinal coils.

4. The influence of the neurovegetative constitution of the subject pre-existent to the operation and which—as recent studies have shown—does not undergo any influence or change on account of illness or surgical intervention.

After these, there remains to be taken

into consideration the possible influence of factors of a chemical nature, of reflex actions which can be explained by the liquid contents of the gastric residue of the stump, for it is known that the peristalsis and the tone of the stomach are, in normal individuals, influenced by chemical factors which act through the nervous vegetative system. In my observations, however, there does not exist any notable difference between the chemical condition of the contents of the stomach as verified on the second and third days, when the stoma appears so tightly closed, and those seen on the fourth day, i.e., after only a few hours more, when the stoma is relaxed and evacuation takes place continuously and in torrents. The examinations are carried out, in fact, with the stomach completely empty of every residue and the products of secretions, and with a liquid that has an identical composition. Therefore, every possible influence of chemical factors on the variation of the functional behavior may be excluded.

This being excluded, it seems to me that a certain value must be assigned to each of the factors considered, and perhaps to others which have escaped my consideration.

In general, there seems to be a basic influence of the pre-existing neuro-vegetative constitution of the subject, which will give the essential clue to those variations in the limits of the phenomena observed by me, in the functional behavior not alone of the residue of the stomach, but of all the intestines. After this, the three other factors considered may be the cause of variations in smaller proportions, with inherent differences in the operative technique, as to the extent of the operation, its duration, etc. Among these it seems to me that the least important is the local mechanical action, because the most important variation, the opening of the stoma, which is observed to be complete at the most in four days, certainly cannot be attributed to the disappearance of the hemorrhage of the tissues, to the edema, or to vascular congestion, which is little changed after the first day. Moreover, if the initial closing of the stoma were due to mechanical action, this would not yield completely in the space of a few hours, but in a slow, gradual manner, and in correspondence to the slow regression of the local traumatic change.

Therefore nothing else remains but to admit as a genetic coefficient of what has been observed the local spasm around the stoma, provoked by reflex actions, either local or generalized. This granted, it will be seen that in subjects with a neuro-vegetative system with sympathetic hyper-excitability the canalization will take place more speedily than in those in which the parasympathetic is predominant; that these subjects will likewise be able to derive benefit from the opening of the stoma with medicaments having a paralyzing action on the vagus; that during the hours immediately following the surgical intervention, the functioning of the stoma and of the residuum of the stomach will not be noticeably influenced by drugs, the effect of which is always transitory, while the action which provokes the spastic reflex is persistent.

DIVERTICULA OF THE STOMACH*

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DIVERTICULA of the stomach are considered rare lesions. The increased use of the roentgen ray in the investigation of gastrointestinal symptoms has shown that diverticula occur more frequently than was once believed, although the incidence is comparatively low. They are probably more frequently diagnosed than published case reports indicate, since they are generally considered to be of little clinical importance and are therefore not recorded. This is unfortunate, as the accumulated data are not sufficient to definitely establish diverticula as positive or negative factors in gastric complaints. Much of the literature is fragmentary and incomplete because most cases have been reported more from an academic than a clinical viewpoint. The frequent inaccessibility of the pouch, the small stoma, the lack of inflammatory changes about the stoma, the inability to secure satisfactory mobilization of the stomach, and the difficulty encountered in resecting the sac when accessible, have made surgical treatment of diverticula of the stomach difficult. These factors have contributed to the limited value of case reports, as few have been operated upon, and fewer have been carefully checked postoperatively in order to determine the effect of removal of the diverticulum on the patient's symptoms.

It has not been our purpose to make an exhaustive review of the literature. We have collected a group of 43 representative cases recorded and have analyzed the clinical data in an effort to determine, if possible, the importance of gastric diverticula as a cause of stomach symptoms. Five personal cases are recorded.

CLASSIFICATION

There have been various classifications of diverticula of the stomach, and numerous hypotheses have been advanced as to their origin. There is no combination of classifications or theories of origin adequate to explain each and every diverticulum. It would seem, from a review of the literature, that a satisfactory classification for the present is as follows:

1. Congenital diverticula. Those resulting from malformation or interruption in development. All layers of the gastric coat are usually intact.

2. Acquired diverticula. Organic disease is instrumental in causing pouching. All layers of the gastric coat are present, but they may be thinned out or broken.

(a) Pulsion diverticula. These are usually attributed to localized increased intragastric pressure.

(b) Traction diverticula. Pouching occurs as a result of adhesions to surrounding organs.

3. False diverticula. These diverticular-like formations are due to the herniation of one or more layers of the gastric coat in the muscularis, and are attributed to trauma.

This classification based on etiology is not always synonymous with the structure found at operation. Allan[1] reported a congenital diverticulum of the stomach in which he thought that the muscular layer was not intact beyond the stoma; and Brandes[32] reported a case of acquired diverticulum with the mural layers intact. Also, the theories satisfactorily explain diverticula in some locations, but fail to explain diverticula of similar structure in other portions of the stomach. The present classifications will undoubtedly undergo some revision as our knowledge of these formations increases.

INCIDENCE

The greater number of articles deal with single or small groups of cases. It is therefore difficult to determine the probable in-

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cidence of gastric diverticula or their relative frequency as compared with diverticula of other portions of the intestinal tract. The following statistics are based upon the roentgen examination of 768 stomachs and 887 colons during the past eighteen months: diverticula of the stomach, 5 cases (0.65 per cent); diverticula of the esophagus, 6 cases (0.79 per cent); diverticula of the duodenum, 33 cases (3.74 per cent); diverticula of the colon, 44 cases (4.96 per cent). Only one diverticulum of the small bowel was observed. The location of diverticula in order of frequency was: colon, duodenum, esophagus, stomach and small bowel. Rigler and Ericksen[25] reported 2 cases (0.49 per cent) of gastric diverticula in a series of 4,236 roentgenological examinations of the stomach. The Mayo Clinic group[26] reported 25 cases (0.02 per cent) of gastric diverticula in a series of 91,532 stomachs examined roentgenologically.

PATHOLOGY

The gross and microsopic appearance of diverticula varies somewhat with the type. True diverticula are usually connected with the stomach by a narrow neck, and there may or may not be thickening around the stoma. These vary little in size, shape, and appearance, and in most cases they have been described as smooth, rounded pouches which are pliable and show little or no evidence of inflammatory changes. This type of gastric diverticulum usually has all three layers of the gastric coat intact.

In the acquired type, the three mural layers are usually present, but they may show some thinning or breaks in one or more layers.

In false diverticula, there is usually an abscence of one or more layers of the gastric coat and a defective muscularis, but changes of specific and primary clinical importance are not present.

Cases have been reported in which pancreatic tissue has been found in diverticula located at the pylorus,[3] and Gile[12] reported a case in which gastric and colic mucosa were found in a diverticulum which was lying adjacent to the pancreas. Infiltration, gangrene, perforation, strangulation, actual diverticulitis or ulceration in a diverticulum, and other similar changes of clinical importance have not been reported in this collected series. Adenomyoma,[25] fibrosarcoma,[25] sarcoma,[7] cancer,[20] and precancerous lesions[21] have been recorded as present in gastric diverticula. I have observed one case (Case v) where an apparently thickened inferior wall, a constant irregularity appearing as a niche which retained barium at twenty-hours, and tenderness localized to the area of the diverticulum suggested an ulcer in a diverticulum. The patient refused surgery and this impression was not confirmed. Another case (Case 1) showed considerable thickening around the stoma.

LOCATION

Diverticula have been reported involving various portions of the stomach, but the larger percentage are observed at the cardiac end, on the posterior wall, and nearer the lesser curvature side. Rivers, Stevens and Kirklin[26] reported 43 per cent at the fundus, 43 per cent adjacent to the pylorus, and 14 per cent removed from the pylorus, in their series of 25 cases. In this series of 43 collected cases, 65 per cent were located at the cardiac end and 23 per cent adjacent to the pylorus, while the remainder involved various portions of the stomach and removed from the pylorus.

ANALYSIS OF 43 CASES

Males—19 (44.2 per cent)
Females—24 (55.8 per cent)
Age periods:
1– 9 years—2
10–19 years—0
20–29 years—6
30–39 years—11
40–49 years—13
50–59 years—9
60 years or more—1

The series can be divided into three main groups for analysis.

1. Cases without symptoms (8, or 18.6 per cent).

(a) Six cases were discovered at routine autopsies in individuals who had died from other causes and had not had symptoms during life which could be attributed to diverticula.

(b) Two cases were in good health and entirely free of gastric symptoms.

II. Cases in which associated pathology could have caused symptoms (20, or 46.5 per cent).

In Group II, the associated lesions which in all probability caused the symptoms were as follows: duodenal ulcer, 6 cases; 2 cases each of cholecystitis, pulmonary tuberculosis, heart disease, malignant degeneration in diverticulum; 1 case each of neurosis, neuritis, gastrocolic fistula, gastric ulcer, dental sepsis, and appendicitis. This group will not be considered further.

III. Cases in which a lesion other than the diverticulum could not be demonstrated as a probable cause of symptoms (15 cases, or 34.9 per cent).

Eleven of these 15 cases were operated upon. The end-result was stated in 4 cases (36.3 per cent), all of which had complete relief of symptons. Unfortunately, the end-result was not stated in the other 63.7 per cent of cases. Four cases did not have surgical treatment. The end-result obtained by medical management was not stated.

The symptoms in order of frequency were as follows: pain in upper abdomen, 66.6 per cent; belching, 20 per cent; vomiting, 20 per cent; dysphagia, relieved by esophageal dilatation, 6.6 per cent. The pain was often described as a burning type of pain and was most often localized to the epigastrium, just beneath the xiphoid, or in the left upper quadrant toward the midline. A few complained of generalized abdominal discomfort. Relief was obtained in 2 cases by alkalies and food respectively; 1 patient was relieved by assuming the supine position; and 1 obtained relief by drinking water. Hurst and Briggs[14] observed that by manipulating their patient in various positions, the diverticulum could be emptied of opaque residue by flushing it with water. It is possible that this may have been the source of relief in this one patient, but generally this method of treatment is considered to be of little value.

It is seen from this analysis that the predominant symptom was pain, often described as a "burning pain," in the upper abdomen, in the epigastrium, beneath the xiphoid, or under the left costal margin. The striking similarity of this complaint in all cases, and the absence of other lesions to explain symptoms, followed by relief in a large percentage of surgically treated cases where the end-result is known, indicate a common etiology. The prevalent conception that gastric diverticula are of little clinical significance seems to need some revision. Gastric diverticula must be considered as a probable cause of symptoms when other lesions cannot be found which could account for the patient's complaints. It is difficult to determine the immediate source of this distress, since there has been a remarkable lack of inflammatory change noted in diverticula which have been removed. Again, the incidence of malignant and precancerous lesions, in this small series of cases, is evidence that cancer in a diverticulum is not a remote possibility. This possibility alone, however, does not justify the excision of each and every diverticulum.

Since gastric diverticula are being discovered more frequently, and since accumulated data indicate that they may be the probable cause of considerable gastric distress in some cases, each case should receive a more critical clinical analysis than is customary at this time, and an effort made to evaluate more correctly the clinical probabilities of gastric diverticula.

REPORT OF CASES

CASE 1. Female, white, aged twenty-four entered the hospital complaining of pain beneath the sternum, abdominal soreness, and nervousness. Nine months before admission she had had a sharp attack of precordial pain with

abdominal cramps, and vomiting. The acute pain was replaced by a dull ache which was variously felt beneath the sternum, at the left costal margin, or in the epigastrium. The precordial pain was made worse by exercise. The dull ache had been persistent in spite of medical treatment. There was also some soreness in the right lower quadrant. She also complained of anorexia, flatulence, constipation, and easy fatigue. She had lost 25 pounds in weight. She had had an appendectomy; the time at which this was done, and the pathology found, were not stated. Physical examination was essentially negative. Temperature was 98.8° F.

Laboratory Findings. Blood: red cells, 4,020,000; hemoglobin, 71 per cent—11 grams; leukocytes, 7,650; Widal negative for *B. typhosus*, paratyphoid A and B; agglutinations for *B. abortus* and *B. melitensis* positive in dilutions of 1:25. Urine negative. Tuberculosis complement fixation and Mantoux tests slightly positive.

A roentgenogram of the chest showed some old calcified nodes in the hila and several smaller calcifications in the lung parenchyma, but no evidence of an active lesion.

A gastrointestinal roentgen examination showed a diverticulum of the cardia, nearer the lesser curvature side, with some thickening around the stoma, which retained barium after eighteen hours, and a right lower quadrant adhesion to the cecum (Fig. 1). There was no disturbance of gastrointestinal motility.

An exploratory operation was done. One small adhesion to the pylorus was found, and the omentum was adherent to the cecum at one point where the appendix had previously been removed. The diverticulum was not found.

Comment. The failure of the surgeon to find a gastric diverticulum does not prove its absence; this has frequently been emphasized in the literature. The illustration is taken from a small roentgenogram made with the roentgenoscopic unit after rotating the patient in a position which showed the diverticulum and the thickening around the stoma to the best advantage. It is highly improbable that the adhesions, which were not causing stasis or obstruction, were the cause of the distressing symptoms of this patient. The diverticulum must be considered as a probable cause of the symptoms.

Case II. A white female, aged fifty-seven, was first admitted to the hospital in May, 1933, complaining of pain in the right lower quadrant, which had been present at various intervals for forty years. She had had a burning sensation and pain in the epigastrium for a

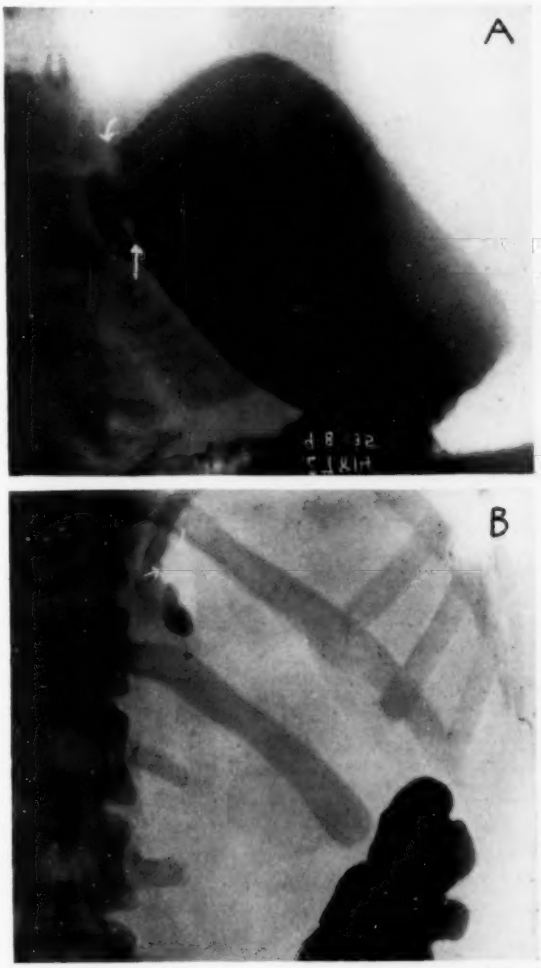

Fig. 1. Case I. *A.* The fibrosis around the stoma is clearly demonstrated. *B.* Retention in diverticulum at eighteen hours.

number of years. This pain usually came on about three hours after meals and was relieved by food. She had obtained some relief by dieting during the previous year. She had always been constipated. She stated that a roentgen diagnosis of duodenal ulcer had been made. She had had ligation of thyroid arteries for hyperthyroidism twelve years before this admission. The physical examination at this time was essentially negative. A diagnosis of recurrent appendicitis was made and the appendix was

FIG. 2. Case II. Typical diverticulum of fundus of stomach. Ulcer of duodenum not demonstrated.

removed. She had been well until December, 1934, at which time she was admitted complaining of nausea, vomiting, loss of weight, and recurring fever. The illness was of insidious onset and was gradually growing worse. The physical examination was essentially negative, except for slight tenderness over the appendectomy scar.

The urine was negative except for a slight trace of albumin. The red blood cells numbered 3,820,000; hemoglobin, 78 per cent—12 grams; leukocytes, 4,200; polymorphonuclears, 58 per cent; small lymphocytes, 36 per cent; large lymphocytes, 4 per cent; myelocytes, 2 per cent. Agglutinations for undulant fever were positive in a dilution of 1:750.

A roentgenogram of the chest was essentially negative. Roentgen examination of the gastrointestinal tract showed a large diverticulum of the cardiac end of the stomach (Fig. 2) which retained barium at the six hour examination but was empty at twenty-four hours; there was also a deformity of the duodenal cap. The colon was normal.

The patient improved steadily with medical management until she was discharged from the hospital.

Comment. The symptoms in this case cannot be attributed to the diverticulum of the stomach.

CASE III. A white female, aged forty-eight, was admitted to the hospital complaining of gas on the stomach, bloating, and pain in the left abdomen. Seven months previously the patient first felt pain in the left side of the abdomen and had the sensation "as if gas or fluid

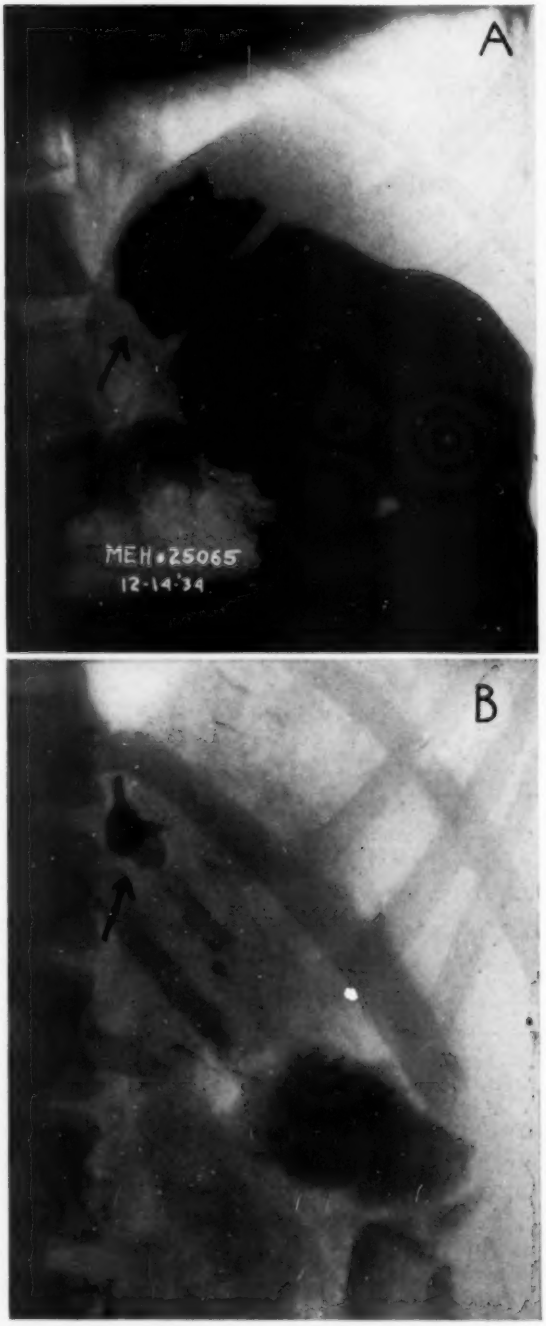

FIG. 3. Case III. *A.* Irregular, large diverticulum at fundus. *B.* Six hour retention in diverticulum.

was being forced through a small opening in the intestine on the left side." Hypodermics were occasionally required for relief from pain. For the past five years she had been bothered with gas on the stomach which seemed to press against the heart, at times causing palpitation. Stools were normal in color, but contained a small amount of mucus at times. The appetite was normal. There were no urinary symptoms. She had lost 7 pounds in weight during the past six months. There was a past history of malaria.

Physical Findings. Marked abdominal tenderness in the left abdomen just below the umbilicus; varicosities over both lower extremities; a large mass of hemorrhoids encircling the anus; external anal sphincter spastic and tight; fissure in posterior anal commissure; uterus enlarged and nodular; no other findings of significance.

Laboratory Findings. Red blood cells, 3,440,000; hemoglobin, 71 per cent—11 grams; leukocytes, 6,850; polymorphonuclears, 66 per cent; small lymphocytes, 32 per cent; large lymphocytes, 2 per cent. Examinations of the sputum for tubercle bacilli were negative. Blood culture negative. Urine negative. Examination of gastric contents and stool revealed normal findings.

Roentgen examination of the gastrointestinal tract showed a large diverticulum of the stomach (Figs. *3A* and *B*), the pouch being irregular in outline, and a small diverticulum of the first portion of the duodenum. The colon was normal. A stereoscopic examination of the kidneys, ureters and bladder was normal.

Microscopic examination of tissue sections passed from the bowel showed mucinous cysts.

The anal fissure was excised and a hemorrhoidectomy was performed.

Case iv. A white female, aged forty-five, was admitted to the hospital complaining of urticaria. Ten weeks before admission she had had a slight skin rash which gradually increased to a severe urticaria. Preceding the onset of the rash she had eaten nothing unusual for her other than lemon ice and pineapple. Sunlight and heat increased the severity of the urticaria. She suffered from frequent headaches. Her appetite was fair. She suffered from chronic constipation. Her father had died of an eczema, and her mother suffered from asthma.

Physical Findings. Temperature, 98.6° F.; pulse, 70; respiration, 20; blood pressure, 152 systolic, 95 diastolic; urticaria; dermographism. No other significant physical findings.

Fig. 4. Case iv. Arrow points to diverticulum. Ulcer of duodenum is not demonstrated on this roentgenogram.

Laboratory Findings. Red blood cells, 3,710,000; hemoglobin, 74 per cent—11.8 grams; leukocytes, 5,560; polymorphonuclears, 68 per cent; small lymphocytes, 26 per cent; mononuclears, 4 per cent; neutrophilic myelocytes, 2 per cent. Blood calcium, 9.4 mg. Plasma chlorides, 600 mg. Blood sugar. 110 mg. Galactose tolerance test: Amount, voided in three hours, 51 c.c.—no galactose excreted. Gastric analysis: No free acid; combined acid 34 per cent; total acid 34 per cent; lactic acid positive; many pus cells; no Boas-Oppler bacilli or sarcinae.

Roentgen examination of the gastrointestinal tract showed a diverticulum of the fundus of the stomach (Fig. 4), duodenal ulcer, peristalsis above the average intensity, marked pylorospasm, and a normal colon. This examination was repeated after antispasmodics and showed essentially the same findings.

The final diagnoses were: angioneurotic edema; urticaria; hypochlorhydria; pylorospasm, secondary anemia and duodenal ulcer.

Comment. The urticaria, hypochlorhydria, and duodenal ulcer could account for all symptoms in this case. This patient had never had the type of upper abdominal pain so frequently complained of by those having diverticula. The diverticulum probably had little or nothing to do with the symptoms.

CASE V. A white female, approximately middle_aged, was sent to the Roentgen Department as an out-patient for gastrointestinal study. She complained of pain in the left upper abdomen, which had no relationship to meals and was relieved by lying on the back. The pain stimulated a peptic ulcer pain.

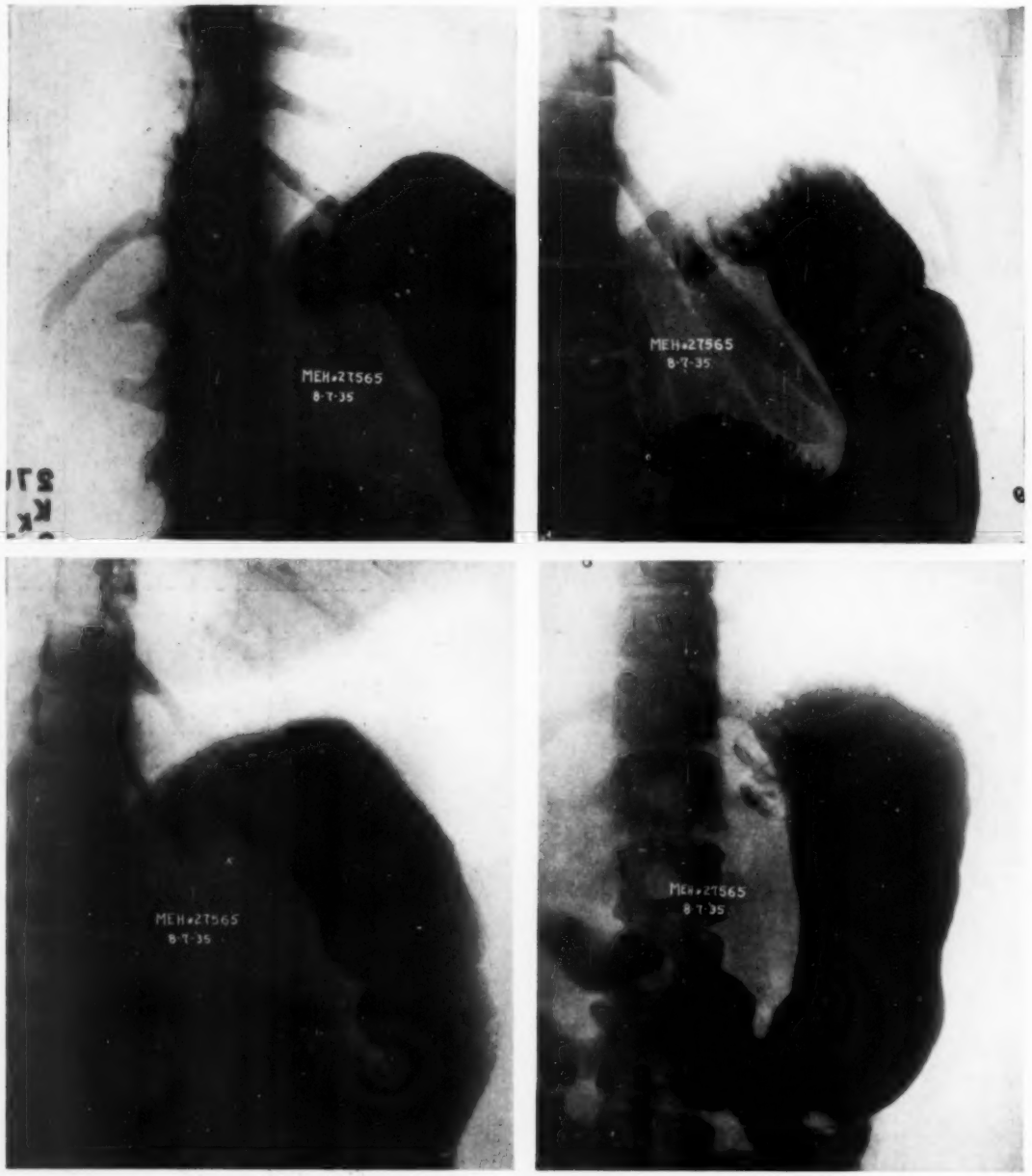

FIG. 5*A*. Case V. Serial roentgenograms demonstrating the thickened inferior wall of the diverticulum and a deformity appearing as a niche. See Figure 5*B*.

The gastrointestinal roentgen examination

showed a typical diverticulum of the fundus of the stomach. The inferior wall of the diverticulum appeared indurated, and the patient's tenderness was localized to the area of the diverticulum. Serial roentgenograms showed what appeared as an ulcer niche in the indurated inferior wall, and there were two small flecks of barium retained in the same area on the twenty-four hour examination (Figs. 5*A* and *B*). A diagnosis of diverticulum of the stomach was made; and due to the above findings, it was thought that there was probably an ulcer in the diverticulum. No other pathology was discovered in the gastrointestinal tract. The referring physician was unable to find any other cause for the symptoms. Surgical excision was therefore advised. The patient consulted another physician; it is said that he advised against the operation, stating that he had seen several diverticula of the stomach and considered them of little significance. The patient refused operation. If an ulcer in a diverticulum had been correctly diagnosed in this case, it would have been rather unusual.

Comment. It is most probable that the diverticulum was the cause of the symptoms in this case, and surgical excision would have been justified.

SUMMARY

The clinical analysis of 43 cases of gastric diverticula of the stomach collected from the literature and 5 personal cases have been presented.

Classifications and theories of origin are not universally satisfactory. The incidence is probably 0.5 per cent or less, and the diverticula are demonstrated more frequently in women than in men. They are located more often at the fundus, but may involve any portion of the stomach.

The diagnosis depends entirely upon the demonstration of the pouch by the roentgen ray, and the failure of a surgeon to find a diverticulum thus demonstrated does not invalidate the roentgen diagnosis.

Diverticulitis, ulcer in a diverticulum, strangulation, gangrene, torsion, and other such factors of clinical importance were not reported in this series of cases confirmed by surgery or autopsy. Malignant degeneration in diverticula has been reported, and the small series of published cases indicates that this is not a remote complication.

The analysis of the clinical data does not seem to justify the often repeated statement in the literature that gastric diverticula are of little or no clinical importance. In 34.9 per cent of the cases reviewed, the diverticulum was the only lesion found in patients complaining of gastric symptoms, variable in degree. The end-result following excision of the diverticulum in 4 cases was stated, all of which were reported as being completely relieved of symptoms. The similarity of symptoms encountered in 34.9 per cent of 43 cases of gastric diverticula indicates a common cause of complaints. Since many diverticula are associated with other pathology, symptoms should not be attributed to the diverticulum until all other causes are excluded. Conversely, when there are

Fig. 5*B*. Case v. Twenty-four hour retention flecks, possibly in ulcer crater. Colon after evacuation.

distressing gastric symptoms in the presence of a diverticulum of the stomach, without associated lesions, the diverticulum should be carefully considered as a probable cause of symptoms. This analysis would indicate that approximately one-third of all gastric diverticula might be a cause of gastric symptoms, and surgical excision may result in complete cure.

All gastric diverticula should henceforth be reported from a clinical viewpoint in an effort to establish their true clinical significance. The accumulated data are insufficient to catalogue properly the clinical importance of these formations, and considerable caution should be exercised in the clinical evaluation of each case.

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THE ROENTGEN DIAGNOSIS OF PATHOLOGICAL PROCESSES OF THE SMALL BOWEL

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THE roentgen ray opened a comparatively little-explored field for diagnosis—the small bowel. Interest has been stimulated by the work of Cannon,[2] Mills,[14] Case,[4] Carman,[3] and others, so that now, with adequate equipment, reasonable care and skill, the roentgenologist can accurately diagnose and locate the various pathological processes that may be found in the small bowel. These processes may be classified: (1) as obstructive or non-obstructive (because the severity of acute symptoms depends to a great extent upon the degree of obstruction), and (2) as to their histopathology. The conditions usually seen (and lesions of the small bowel, except duodenal ulcer, are relatively rare) may be enumerated as follows:

1. *New Growths* (malignant or benign). These are rare. Primary carcinoma and lymphosarcoma are occasionally seen, as are myomas, lipomas, adenomas and fibromas.

Malignant tumors of the small bowel are of such importance that they cannot be briefly passed. Rutishauser[16] reports 6 cases of carcinoma of the duodenum observed between 1900 and 1931 at the Pathological-Anatomical Institute in Geneva. In one case the tumors were multiple, and were considered to be derived from Brunner's glands in the first portion of the duodenum. In the other 5 cases, the growths were situated nearer the papillae of the biliary and pancreatic ducts. Histological examination revealed all of these tumors to be adenocarcinoma, with marked variation between the more benign adenomatous and the malignant carcinomatous forms of growth. Metastases to the regional lymph nodes were found in 3 cases, to the liver in 3 cases, and to the peritoneum in 1; no metastatic tumors were present in 2 cases. Four of the patients were males between fifty and eighty-three years of age; and 2 were females, fifty-eight and seventy-four years of age respectively.

Dominici[7] reports a case of carcinoma of the duodenum in a man aged forty-seven. The only roentgenographic evidence was considerable deformity of the duodenum. At operation, the posterior duodenal wall was found adherent to the vena cava, bile duct and right gastro-epiploic artery. Owing to infiltration of the tumor on this wall, the tumor was impossible of removal. Specimen taken for histological examination revealed adenocarcinoma.

Mateer and Hartman[12] reported 6 cases of carcinoma proved by autopsy in 176,000 admissions to the Gastrointestinal Division of the Medical Department of the Henry Ford Hospital, Detroit. They further state that representative statistical reports indicate that duodenal carcinoma constitutes 0.25 per cent of all carcinomas, and from 2.3 to 3.0 per cent of intestinal carcinomas.

Meyer and Rosenberg[13] report an incidence of 0.53 per cent of cases of carcinoma of the duodenum in a series of 569 cases observed at Cook County Hospital, Chicago.

Eichelter[8] reports a case of carcinoma of the duodenal peduncle four years after a subtotal resection of the stomach for benign ulcer. The duodenum perforated into the free abdominal cavity.

Schofield[17] reports a case in a female, aged thirty-five, and states that metastases occur only very late in carcinoma of the duodenum, and advises the implantation of radon seeds at the time of operation. He believes this treatment to hold greater hope of a permanent cure.

Rankin and Mayo[15] report 55 cases of primary carcinoma of the small bowel, an incidence of 0.062 per cent. These include

24 cases collected by Judd[11] up to 1919. The age incidence ranged between thirty-two and sixty-nine years, the age of the greatest preference being forty-seven years. Histologically, the tumors were chiefly adenocarcinoma. The duodenum was involved in 20 cases, the jejunum in 21, and the ileum in 14. Metastases were regularly present, most frequently in the peritoneum; then liver, lungs and long bones in decreasing frequency. They feel that the prognosis is always unfavorable, and operation prolongs life only briefly. In the cases reported, symptoms were present from two months to five years—most frequently from fourteen to fifteen months.

Dewis and Morse[6] report 12 cases of cancer of the duodenum, and state that only 3, or 25 per cent, showed metastases.

Dahl-Iversen and Nissen[5] discuss the importance of occult bleeding in the diagnosis of carcinoma of the gastrointestinal tract. They state that in a series of 110 cases, 95 per cent of cases of carcinoma of the stomach showed occult blood. Persistent bleeding was demonstrated in 74 cases (67 per cent) of carcinoma of large and small bowel, intermittent bleeding in 28 cases (25.5 per cent), and absence of bleeding in 8 cases (7.3 per cent). From these figures it may be stated that occult blood can be demonstrated in 93 per cent of cases of carcinoma of the bowel, and in 95 per cent of cases of carcinoma of the stomach. In cases of intermittent bleeding with negative results, frequent examinations are necessary.

Soper[18] also calls attention to the importance of tests for occult blood in suspected cases of gastrointestinal cancer, and advocates the Weber modification of the guaiac test, as the benzidine, phenolphthalein and other tests are too sensitive to be reliable.

2. *Tuberculosis*, which is so well described by Brown and Sampson,[1] is stated by them to be found in 50 to 80 per cent of all pulmonary cases coming to autopsy. They quote Fenwick and Dodwell[9] as stating that in 500 autopsies the ileocecal region was affected in 85 per cent, the jejunum in 28 per cent, and the duodenum in 3.4 per cent.

3. *Congenital Anomalies and Displacements*. Anomalies are of various kinds. A case is presented herewith. Displacements, while not intrinsic pathology of the small bowel, are of sufficient importance to be mentioned. Pelvic tumors, pregnancy, cysts and fibroids, displace the small bowel upwards. Tumors of the head of the pancreas displace the second and third portions of the duodenum outward. Enlargements and tumors of the spleen cause displacement downward and medially. Kidney tumors, such as hypernephroma, cause forward displacements. Liver enlargements or tumors cause downward displacements, and mesenteric tumors cause displacements depending on their location and size. Appendiceal abscesses may also cause displacement.

4. *Diverticula of the Jejuno-ileum*. These may be single, as Meckel's diverticulum; or multiple, and part of a generalized diverticulosis of the bowel. Their size varies from that of a small pea to that of a moderate-sized orange.

5. *Simple and Typhoid Ulcers*. Simple ulcers of the small bowel (of which the duodenal bulb is not considered a part), when seen, are more frequent in the jejunum, and perhaps most frequent at the site of a gastrojejunostomy stoma. Typhoid ulcers are infrequently seen, due to the almost complete eradication of this disease; and rarely indeed are typhoid patients roentgenographically examined when acutely ill.

6. *Foreign bodies* are of many and various kinds. A case of small bowel obstruction caused by an impacted gallstone is presented herewith. This is a rare finding. The stone usually enters the stomach or small bowel by auto-anastomosis.

7. *Adhesions and bands*, after the first year of life and during childhood, are not an uncommon cause of small bowel pathology. They cause kinks, displacements and malpositions, with resulting limitation in mobility and motility which may result in

partial or complete obstruction and interference with blood supply, causing necrosis and gangrene. Graham,[10] quoting a Massachusetts General Hospital report of 239 cases of obstruction treated by operation, gives the causes and frequency as follows (strangulated hernia, the commonest cause, and tumor of the intestine, the next in frequency, are not included):

	per cent
1. Early postoperative (up to 4 weeks)	47
2. Late postoperative (after 4 weeks)	47
3. Bands and adhesions (no previous operation)	47
4. Intussusception	47
5. Volvulus	25
6. Meckel's diverticulum	13
7. Mesenteric thrombosis	6
8. Internal hernia	3
9. Congenital anomalies	2
10. Obstruction by stone	2

Other causes, not previously mentioned, are traumatized small bowel, and injury to the mesentery. Gas cysts of the intestinal wall are occasionally seen, and usually accompany other obstructive lesions of the small bowel. They vary in number from a few discrete nodules to massed clusters which may of themselves occlude the intestinal lumen. They usually disappear upon correction of the accompanying lesion, but occasionally resection of the affected area may be necessary.

Since practically all lesions of the small bowel give rise to a greater or lesser degree of obstruction, it may be well to give at least a general résumé of this phase of pathological conditions of the small bowel. High acute intestinal obstruction is a rapidly fatal condition unless promptly diagnosed and immediately relieved. It is almost axiomatic that the "higher the obstruction, the more quickly death will ensue." The cause of death is toxic absorption from the intestine, and that syndrome which (for want of a better term) is called shock. Sepsis and peritonitis are not essential causes, though frequently present. The clinical signs and symptoms may be enumerated as follows: continuous pain at or above the umbilicus, vomiting, which eventually becomes stercoraceous; scanty urine, low in chlorides; complete obstipation; normal to subnormal temperature; slight increase in pulse rate; dehydration, resulting from loss by vomiting and lessened fluid intake; possible leukocytosis; moderate to absent abdominal tenderness; gurgling on auscultation of the abdomen (this is not present in paralytic ileus); asymmetrical distention of the abdomen. A strangulated loop of gut is occasionally felt by palpating the abdomen.

The location of the obstruction is obviously a matter of importance. The following signs and symptoms are clues to the level of the obstruction: rapid development of toxemia, central or upper abdominal distention, and regurgitant vomiting, indicate small bowel rather than colonic obstruction; bile-stained duodenal content vomitus, which does not become fecal, indicates a high jejunal obstruction; a localized or asymmetrical distention is suggestive of strangulation, volvulus or distended gut above the point of obstruction.

The probable cause, and hence the location of the obstruction may be inferred from the patient's age. In the new-born, congenital defects and volvulus may be found. During the first year, intussusception is a common cause. As childhood progresses, bands and adhesions (either spontaneous or postoperative) are relatively more common. In adult life, bands and adhesions predominate. As age progresses, the rare cases of impaction of a gallstone are more likely to occur. In general, it may be stated that up to cancer age, conditions causing acute obstruction affect the *small bowel.* After this age has been reached, conditions causing occlusion of the *colon* become increasingly frequent.

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that full advantage may be taken of this method of examination, a proper conception of the anatomy and physiology of the small bowel must be had; and adequate training in the use of the apparatus and evaluation of the findings must be acquired.

The small bowel consists of the duodenum, jejunum and ileum; and is approximately 7 meters (22 ft.) in length, the duodenum being the shortest portion, 25 cm. (10 inches). The remaining upper two-fifths is jejunum, and the lower three-fifths, ileum. There is no sharp line of demarcation between the jejunum and ileum; anatomically, however, a gradual change takes place, so that sections of the beginning of the jejunum and the end of the ileum would show rather marked morphological differences. The jejunum is wider, being approximately 4 cm. (the ileum 3.75 cm.), is more vascular, the valvulae conniventes are larger and more thickly set and its villi are larger than in the ileum. The aggregated lymph nodes (Peyer's patches) are less frequent than in the ileum, are smaller, and tend to assume a circular form. When outlined with contrast medium, the jejunum has a feathery, snowflake appearance, and the ileum is sausage-like.

The jejunum, for the most part, occupies the umbilical and left iliac regions, while the ileum occupies chiefly the umbilical, hypogastric, right iliac and pelvic regions.

The roentgen method of examination of the small bowel is a combined use of roentgenoscopy and roentgenography, using a contrast medium—usually purified barium sulphate. If sufficient information is obtained to warrant a diagnosis of obstruction by roentgenoscopic and flat-film studies, contrast medium should not be used, because the hard, inspissated masses of barium may interfere greatly with the surgical procedure necessary to afford relief. The roentgenoscopic method depends on the fact that the small bowel normally does not contain gas or fluid in sufficient quantities to form a fluid level, visible when the patient is examined in the upright position. This method also gives some idea of the size of the small bowel, the location and duration of the obstruction. The folds of Kerkring stand out in contrast to the gas-filled lumen, giving what Case[4] describes as "herring-bone" appearance. When the loops of the distended gut lie parallel, a "ladder-like" arrangement is seen, which indicates that immediate operation is imperative. This method has the advantages of speed and simplicity, and does not have the disadvantage of filling the bowel with a substance which may be the cause of difficulty and possible disaster. A wet-film reading can be given in a few minutes, and if the patient is unable to stand or sit, films may be made with the patient lying on his side. In desperately ill patients, satisfactory information may be gained by the use of a portable unit.

The method of using a contrast medium is particularly applicable to cases of partial obstruction in which the time element is not paramount. Twenty-four hours is usually required, and hourly observations are necessary until the medium has passed into the colon. This method is of value in most of the conditions listed above, such as tuberculosis, hernias, anomalies, partially obstructive new growths, diverticula, displacements, ulcers and adhesions. A contrast meal is given, using the minimum amount of barium sulphate. This should be slightly above body temperature so that gastric peristalsis will not be delayed. Almost immediately the meal begins to leave the stomach in spurts, as successive peristaltic waves reach the pylorus.

Progress through the small bowel takes place in three ways: rhythmic segmentation, pendulum movement, and peristaltic rush. While the rate of movement has a normally wide range, it may be stated that progress through the jejunum is more rapid, this portion usually being practically empty at the six hour examination. The head of the column reaches the cecum in about four hours, and normally the ileum is empty in not less than nine hours.

Twenty-four hour retention in the ileum may be considered pathological if there are no factors such as higher obstructive lesions, pyloric stenosis, gastric ulcer or duodenal ulcer to interfere, or lower obstructive lesions such as cancer of the cecum. An incompetent ileocecal valve may also account for the twenty-four hour ileal retention; this, however, is actually a regurgitation rather than a retention. The opposite condition is seen (but rather infrequently) when the entire meal has passed into the colon in six hours (somewhat more or less), when hypermotility is said to exist. Repeated and detailed examinations should be made to determine the cause or causes, some of which are tuberculosis, simple ulcer, achylia gastrica, scirrhous carcinoma. A too large gastroenterostomy stoma or purgative drugs may cause a pseudo-hypermotility.

REPORT OF CASES

Case I. *Obstruction Caused by Adhesions, Resulting from Diverticulitis of the Sigmoid.*

W. O. T., white, male, married, painter, admitted to Sibley Memorial Hospital on December 5, 1932. History shows many years of digestive disturbances. Operation for gastric ulcer and appendicitis nine years prior to admission. Present acute illness began two days prior to admission, with sudden abdominal pain and weakness. The following day the pain increased, and there was nausea and vomiting. A physician was called, and patient referred to the hospital.

Flat film of the abdomen showed some evidence of small bowel obstruction, probably in the ileum. Blood examination showed hemoglobin 58 per cent; red blood cells, 3,750,000; white blood cells, 17,500 with 95 per cent polymorphonuclears. The urine showed a heavy trace of albumin, an occasional hyaline cast and many red blood cells. The patient was immediately operated upon.

Operative Findings. "Right rectus incision. On opening the peritoneum, free pus was found over the cecum. Lower ileum was distended; upper ileum and jejunum greatly distended. The small bowel was traced to the brim of the sacrum, where it was found adherent and kinked. The adhesions were liberated, and the kink brought to the surface. Gas immediately entered the cecum. Two large cigarette drains were inserted and the incision closed."

Four days later a jejunostomy was performed, because of recurrence of the symptoms of obstruction. Patient died the following day.

Autopsy showed the following: (1) chronic diverticulitis of the sigmoid, with ulceration of the appendices epiploicae; (2) generalized peritonitis (fibropurulent type); (3) intestinal obstruction (surgical), with jejunostomy and paralytic ileus proximal to this point.

Case II. *Obstruction Caused by Adhesive Band (No Previous Operation), with Congenital Anomaly.*

A. L., white, female, aged thirteen, schoolgirl, admitted to Sibley Memorial Hospital on January 29, 1934. Illness began the day of admission, with sudden severe attack of abdominal pain, with vomiting. The pain localized on the right side. Physical examination negative except for marked tenderness in the right lower quadrant. Urinalysis showed a heavy trace of albumin and abundant red blood cells. Operation on January 30, 1934. (Preoperative diagnosis, "acute appendicitis.")

Operative Findings: "Ileocecal junction in right upper quadrant, directly under the liver. Dissection and search was made for the appendix, but none found. Many large lymphatic glands noted."

Roentgen Examination, February 5, 1934. "Roentgenoscopic and roentgenographic examination of the colon with the barium enema shows partial obstruction of the small bowel (probably ileum) in the right upper quadrant. A congenital anomaly is noted: the colon is entirely on the left side, with the cecum in the pelvis on the left." (Note: What the surgeon thought was ileocecal junction was in all probability hepatic flexure; the partially obstructed small bowel was, no doubt, mistaken clinically for acute appendicitis.)

The patient made an uneventful recovery and returned to her home. She then had recurrent attacks, and was operated upon again on April 16, 1934. The operative findings were as follows:

"Right upper outer rectus incision. Multiple adhesions about the greater curvature of the stomach, duodenum, and for about 12 inches along the jejunum, with partial obstruction. Etiologic factor in the causation of these adhesions is not determined. The entire colon is

on the left side, the cecum and appendix being in the left pelvis. Pelvic organs normal. Operation: freeing of adhesions and appendectomy. Recovery proceeding uneventfully."

Case III. *Small Bowel Obstruction Due to Impacted Gallstone.*

G. M. I., white, female, married, housewife, aged sixty-five, admitted to Sibley Memorial Hospital on August 26, 1931. Patient was taken suddenly ill four days prior to admission. The chief complaints were abdominal pain, nausea and vomiting. On admission the patient was desperately ill and further history was not obtainable.

Roentgen Examination, August 27, 1931. "Flat film of the abdomen shows acute intestinal obstruction, probably in the jejunum near the ileum. There are shadows in the right upper quadrant, probably gallstones."

Because of the patient's profound illness, further studies to confirm the probable gallstone diagnosis were not made.

Blood studies showed hemoglobin, 87 per cent; red blood cells, 4,210,000; white blood cells, 9,000, with 87 per cent polymorphonuclears, 12 per cent lymphocytes, 1 per cent mononuclears; non-protein nitrogen 57 mg. per 100 c.c. (normal 25 to 35 mg.). Urine showed faint traces of albumin and sugar.

Operative Findings. "Enterostomy and extraction of gallstone. Very large gallstone in small bowel. Gallbladder not examined. Postoperative condition not good."

The patient did not react well, and expired the following day. Autopsy was not obtained.

Case IV. *Small Bowel Obstruction Due to Scirrhous Carcinoma and General Peritonitis.*

C. O., white, male, aged fifty-four, married, stationary engineer, admitted to Sibley Memorial Hospital on November 7, 1932. Two months prior to admission, patient noted swelling of abdomen, and had some nausea and vomiting. Hospitalized elsewhere, and large amount of fluid drawn off by paracentesis abdominis; patient discharged. Shortly thereafter he noticed a mass in the lower abdomen. Fluid re-appeared; nausea and vomiting increased. Had lost considerable weight in the two months prior to admission. Appetite poor. Bowels move irregularly, infrequently, and with great difficulty.

The attending physician, believing the abdominal tumor to be associated with the kidneys, requested roentgen study of the genitourinary tract. This was reported as follows: "No evidence of pathology in the genitourinary tract. There is some suggestion of small bowel obstruction."

The patient was apparently not dangerously ill, and a gastrointestinal study was commenced the following morning. This showed an absence of gastric peristalsis, and a rapid pouring of gastric content into a markedly dilated duodenum. The small bowel was matted and fixed, and motility and mobility were markedly decreased. There was 75 per cent residue in the stomach and upper bowel at five hours, and small amounts were noted in the small bowel at twenty-four hours. Conclusion: a chronic inflammatory process of the stomach and small bowel, with marked stasis and partial obstruction.

The urine showed a heavy trace of albumin, abundant fine and coarse broad granular casts. Sugar was slightly positive.

Blood examination showed hemoglobin 52 per cent; red blood cells, 2,700,000; white blood cells, 9,500; polymorphonuclears, 84 per cent; lymphocytes, 16 per cent; non-protein nitrogen, 68 mg. per 100 c.c.

The patient's course was progressively downward, and he died on November 23, 1932. Autopsy showed the following: (1) scirrhous carcinoma of the stomach, with extensive ulceration and induration of the walls; (2) chronic diffuse adhesive peritonitis, with partial obstruction at the duodenojejunal junction; (3) chronic interstitial hepatitis, with toxic changes; (4) early nephritis, with toxic nephrosis.

Case V. *Small Bowel Obstruction Due to Cancer of the Duodenum.*

M. W., white, female, married, aged fifty-nine, admitted to Sibley Memorial Hospital on November 29, 1929. For the past five years she had had attacks of epigastric pain with fullness and belching; no nausea or vomiting. In September, 1929, she had mild attacks of vomiting, with a "drawing" type of gastric pain which was relieved by vomiting. These became increasingly severe and frequent. The patient began to lose weight; the appetite diminished. Bowels constipated.

Roentgen study of the gastrointestinal tract showed a markedly dilated and atonic stomach and duodenal bulb, with 75 per cent gastric residue at five hours, and 50 per cent at twenty-four hours. The roentgen diagnosis was "ob-

tructive lesion of the second portion of the duodenum," and operation advised.

Urinalysis showed a trace of albumin, an occasional red blood cell, a few hyaline casts.

Blood examination showed hemoglobin, 65 per cent; leukocytes, 11,550; erythrocytes, 3,490,000.

Operative Record. "Midline incision. Hard nodular mass about the size of a plum felt in the second portion of the duodenum. Pylorus distended about 2 inches with gas. Gallbladder normal. Gastroenterostomy performed." Postoperative diagnosis: "Mass in duodenum, possibly carcinoma. Immediate postoperative condition, poor."

The patient's recovery was slow, but otherwise uneventful. She was discharged from the hospital on December 10, 1929, in fairly good condition. Her subsequent convalescence was not satisfactory. About one month following her discharge, an obstructive jaundice developed. There was rapid loss of weight, anemia and cachexia, and the patient expired in a few weeks of what her physician described as a generalized carcinomatosis, very probably metastatic from the duodenal mass. Autopsy was not obtained.

Case vi. *Adenocarcinoma of the Ileum.*

J. T., white, male, aged fifty-five. Complained of abdominal pain, vomiting of food ingested several days previously, constipation, stools small—no blood. During attacks, pain appeared regularly every five minutes, accompanied by gurgling. After several such episodes the pain subsided. A history of pulmonary tuberculosis was elicited, for which, when a young man, the patient spent a year in a western state. The lungs showed no evidence of disease at time of admission. The constant use of alcohol and tobacco was admitted. The patient was, and had been for some time, under treatment for syphilis. The blood Wassermann was said to be negative at time of admission.

Physical examination reveals a thin, poorly nourished patient. The pulse is 80 and regular; the blood pressure 115/80. The abdomen is soft; shows no distention, palpable masses or tenderness. Active peristaltic movements are felt, and gurgling sounds are heard and felt.

Roentgen examination shows considerable residue in the ileum twenty-four hours after the ingestion of a barium meal. Diagnosis: obstructive lesion in the ileum.

Operation under spinal anesthesia disclosed a small annular tumor constricting the ileum, with marked thickening, hypertrophy and dilatation of the ileum above the tumor. The tumor was resected, and a side-to-side anastomosis done, with an ileostomy done in the proximal bowel. Death occurred twelve days after operation. Histological examination of the specimen showed adenocarcinoma.

Case vii. *Small Bowel Obstruction Caused by Meckel's Diverticulum of the Ileum.*

I. C., white, male, aged sixty, admitted to Sibley Memorial Hospital on October 9, 1934. Chief complaint, vomiting. Two days prior to admission, patient became constipated and started vomiting. This was difficult to control. Had no pain or other complaint except the persistent vomiting.

Physical examination shows a well-developed, fairly well-nourished male, lying quietly in bed, in some apparent discomfort from hiccough. The heart and lungs show no abnormality. The abdomen is soft, no rigidity or distention. A small mass is felt in the left lower quadrant, which is slightly tender.

Blood examination shows hemoglobin 67 per cent; red blood cells, 3,700,000; white blood cells, 17,400; 95 per cent polymorphonuclears.

Urine examination on admission shows a small amount of albumin, and faintly positive sugar. Specific gravity, 1.002; few hyaline casts. Preoperative specimen: faint trace of albumin, sugar negative, abundant hyaline casts

Roentgen examination of the stomach and duodenum shows a large atonic stomach, with considerable dilatation of the duodenum, and an obstruction in the first portion of the jejunum which is almost complete, only a minimum amount of the meal passing through in six hours.

Operation under ethylene anesthesia revealed a Meckel's diverticulum of the lower third of the ileum, which was resected, with a small portion of gut. Adhesions resulting from inflammatory change in the diverticulum caused the obstruction high up in the jejunum. Patient made an uneventful recovery.

Case viii. *Intestinal Obstruction Caused by Polyp of the Small Bowel and Intussusception.*

F. H., white, male, aged thirty, clergyman, admitted September 20, 1934, Chief complaint, attacks of severe abdominal pain for the past three months. These attacks had no relation to the ingestion of food. Vomiting was

usually present, projectile in type. During attacks, the knee-chest position was the least uncomfortable. Several weeks previous to admission, a complete examination made elsewhere showed no evidence of pathology, and a diagnosis of neurosis was made.

Physical examination reveals an under-developed and poorly nourished male of effeminate appearance, apparently in excruciating pain. The temperature is 98.0° F., pulse 68. The abdomen is soft, and unusually yielding to palpation. There is no evidence of localized tenderness or suspicious masses. Peristalsis can be heard over the entire abdomen."

The following morning the temperature was 99.2° F., the pulse 96. A palpable mass was noted just to the left of the umbilicus.

Roentgen examination (flat film) showed the colon and some loops of the small bowel distended with gas, suggesting obstruction.

Blood Examination. Hemoglobin, 83 per cent; red blood cells, 4,350,000; white blood cells, 10,400; polymorphonuclears, 89 per cent.

Operation, under ethylene anesthesia, revealed a large intussusception of the ileum, caused by a polyp about the size of a walnut. The ileum was gangrenous for approximately 18 inches. The polyp was excised and the gangrenous bowel resected. The patient expired the following day. Cause of death, postoperative shock and hemorrhage.

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HERNIA OF THE MEDIASTINUM*

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THE introduction of collapse therapy marked the greatest advance in the treatment of pulmonary tuberculosis during the last century. There are, however, certain complications which attend its use and make the procedure one that must be used with due precaution.

During the induction of pneumothorax, there is some movement of the mediastinum as a whole due to the altered mechanics of the intrathoracic space. Herniation of the pneumothorax cavity through the mediastinum into the opposite chest space may also occur at certain weak spots in the mediastinum. The hernia sac may be small with few symptoms and signs, or it may be so large as to have serious or even fatal consequences, and present the signs of localized pneumothorax.

According to Sewall,[8] hernia of the mediastinum was first described by Nitsch,[6] who gave an excellent description of the anatomy which makes its occurrence possible. This has been the subject of many French and Italian articles. Comparatively few articles have appeared in English, but those by Packard,[7] Habliston,[3] Sewall,[8] and others, are notable.

The increase in popularity of collapse therapy with the occasional accompaniment of mediastinal hernia with serious and sometimes fatal consequences necessitates an adequate idea of the mechanism by which it occurs, its diagnostic features, its clinical significance and treatment. Study of this mechanism presupposes some knowledge of mediastinal anatomy and respiratory mechanics.

ANATOMY OF THE MEDIASTINUM

The mediastinum is the middle compartment of the thoracic cavity. Anteriorly it is bounded by the sternum, posteriorly by the spine, laterally by the mediastinal pleura. Ordinarily the mediastinum is divided into four compartments: superior, anterior, middle and posterior. For our purpose, the division proposed by Nitsch[6] is better. If a horizontal plane is passed through the midportion of the trachea, the thoracic cavity is cut into two portions.

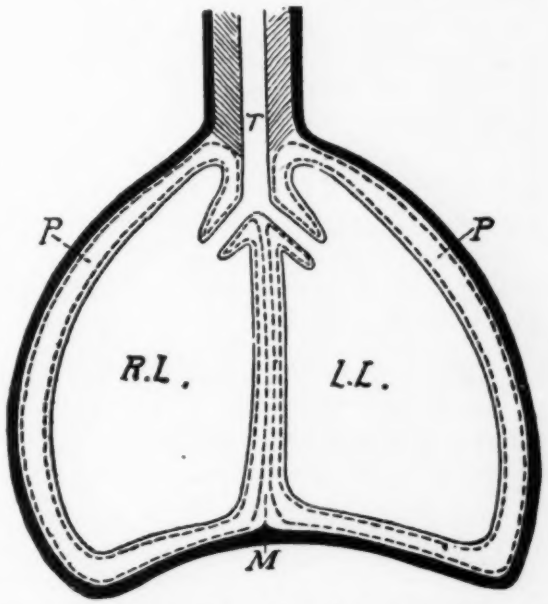

FIG. 1. Schematic illustration of relations of parietal and visceral layers of pleural sacs, and position of the mediastinal space (from Howell's Textbook of Physiology).

The anterior contains the remains of the thymus, lymph nodes and loose connective tissue; the posterior contains the heart and great vessels. As we are not primarily concerned with the mediastinal contents, only those structures will be mentioned which directly bear on mediastinal hernia. Figure 1 shows the mediastinal pleura, which forms the lateral walls of this compartment. It is composed of fibrous and elastic tissue covered with flat epithelium. It is thin, and elastic. At the sternal attachments of the parietal pleura, where the

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mediastinal pleura takes its origin, the right pleural sac may be attached to the left of the midline or to the left sternal border. The pleural sacs thus overlap. We would expect these thin transparent structures to depend upon the mediastinal contents for their support and, in cases of increased intrathoracic pressure, we would expect wide displacement where this is lacking.

Due to lack of adequate support, two weak places exist in the mediastinum. The anterior one is just behind the sternum, the posterior one is just anterior to the area of the fifth to the tenth dorsal vertebrae. The anterior one is bounded in front by the sternum, laterally by the mediastinal pleura, inferiorly by the diaphragm, and superiorly by the neck. Posteriorly, the mediastinal pleura encloses a potential space bounded in front by the esophagus and the heart, posteriorly by descending aorta and the spine.

EFFECT UPON THE MEDIASTINUM OF INJECTION OF AIR INTO THE PLEURAL CAVITY

If sufficient air is introduced into the pleural cavity, the normal mediastinum is displaced in part or as a whole. If the mediastinum has been rendered rigid by inflammation, or if pleural or pleuropericardial adhesions exist, its position may remain unaltered. If a certain intrathoracic pressure is exceeded, herniation of the mediastinum may occur through these so-called weak spots mentioned above. The most common site for such herniation to occur is anteriorly just behind the sternum from the first to the third ribs. Here the pleural sacs come in contact. They are very thin and distensible. According to Murphy[5] a foramen may exist here between the two pleural sacs in human beings. This is common in dogs, but less frequent in guinea pigs and rabbits. It is always found in monunguals.

Graham and Bell[2] found that when a large amount of air was introduced into the pleural cavity of dogs, a flopping of the mediastinum occurred in the anterior portion. Often with an increase in the respiratory excursion, rupture occurred and a bilateral pneumothorax followed.

Sewall[8] and Nitsch[6] introduced air into the pleural cavity of prepared cadavers and watched these anterior hernias develop as pressure was increased sufficiently. These hernias usually originate on the left side and project into the right side. Twenty-four out of the 39 recorded in Packard's[7] paper were left sided and protruded into the right side; the remainder were in the reverse direction.

Hernias of the posterior mediastinum are quite rare. Only one case was reported by Packard in a series of 30 cases collected from the literature and 9 cases of his own.

In the posterior mediastinum with a relatively high intrathoracic pressure on the right side, the corresponding parietal pleura may be pushed between the heart and spine into the left side. The bulging of the hernia from the left side into the right side posteriorly is rare because of the valve-like action of the esophagus which prevents it.

ROENTGEN SIGNS OF HERNIA

By roentgenoscopic examination, one can watch the progression and regression of the hernial sac.

In expiration, a crescentic band of high light, bounded by a narrow dark line at its outer border, emerges from shadows of the spine and great vessels and flows laterally over the contralateral lung as the depth of expiration increases. The crescentic highlight reaches its greatest dimension when expiration is completed. When inspiration begins, the crescent begins to recede gradually and at the end of inspiration ebbs again into the shadows of the spine and great vessels. The hernia can be seen more clearly if the patient is rotated slightly into an oblique view. Sewall's[8] comparison of the hernia in expiration and inspiration to a strongly and weakly deflated balloon is concrete, apt and accurate.

Because the hernia is greatest in size at

the time of full expiration, films should be made of suspected cases at this interval rather than the usual time of full inspiration. Small mediastinal hernias may be missed when films are made in the usual manner. Films taken in expiration show a shadow of decreased density with a convex lateral border. This emerges from the shadow of the great vessels above and proceeds laterally and downward, gradually merging with the shadow of the spine and great vessels below.

Variation in the size of the hernia during the respiratory phases may be explained as follows: When the chest wall and the diaphragm on the affected side make the usual respiratory excursion, the collapsed lung changes very little in volume so that an adjustment must be made somewhere. The volume of the air in the pleural cavity is invariable, as it is not changed by the passage of air through the trachea. So, in expiration the mediastinum moves over as the diaphragm ascends; the chest wall contracts and the hernia bulges into the contralateral pleural cavity. In inspiration, the reverse occurs; the hernia recedes as the diaphragm descends and the chest wall expands.

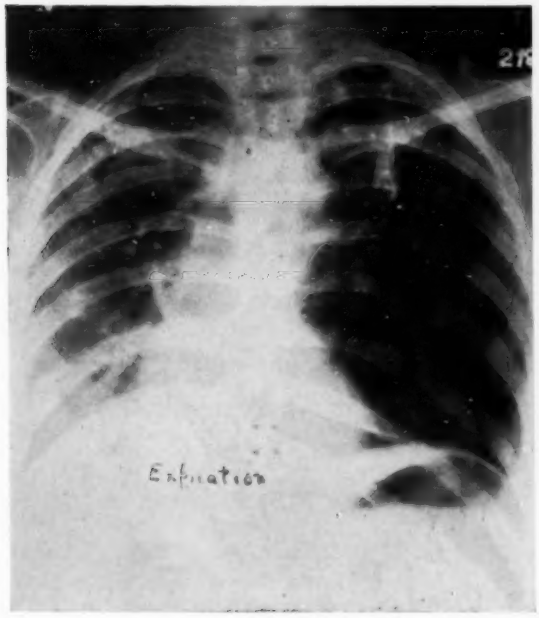

Fig. 2. Case 1. Roentgenogram made at height of expiratory phase shows a mediastinal hernia protruding into the right pleural cavity.

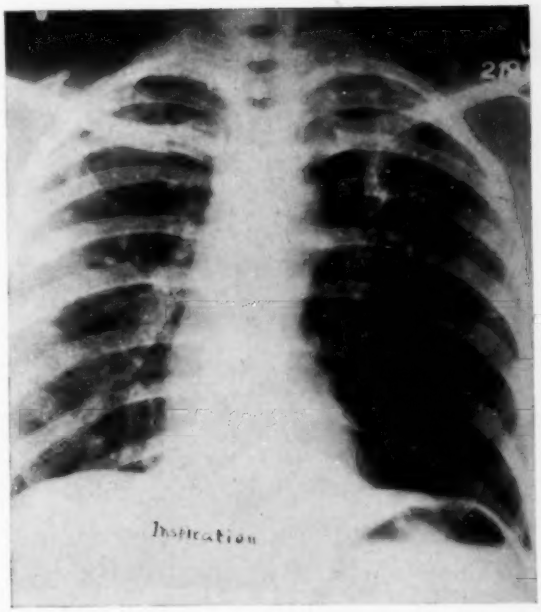

Fig. 3. Case 1. Roentgenogram made at height of inspiratory phase. The mediastinal hernia noted on the previous film is not visible.

CASE HISTORIES

Case 1. M. H. (No. 219171). Colored female, aged forty. History of pulmonary tuberculosis for fifteen years. Positive physical findings. Sputum positive. Roentgenograms show evidence of pulmonary tuberculosis with some calcification in both upper lobes.

Patient entered this hospital July 6, 1935, and collapse therapy was instituted. Pneumothorax was the method employed. Air was introduced into the left pleural cavity at intervals of approximately one week. There was an average of 425 c.c. of air introduced at each refill. After several months the intrathoracic pressure became positive and on November 26, 1935, after a refill of 600 c.c. of air, the pressure became -5 to $+4$. At that time roentgen films showed suggestion of mediastinal hernia into the right chest. On December 6 there was a definite mediastinal hernia visible anteriorly in the right chest (Figs. 2, 3 and 4). With a decrease in the interval and size of the refills, the intrathoracic pressure decreased, and the size of the hernia was decreased. It was still visible roentgenoscopically for several months during continued collapse therapy.

Case 11. L. D (No. 146337). White female,

Fig. 4. Case I. Roentgenogram in lateral position at height of expiratory phase. The mediastinal hernia pocket can be seen lying just beneath the sternum.

aged twenty. In 1930, there was evidence of early tuberculous changes in the right apex. The hilar glands were calcified and the tuberculin test positive. In 1935, there was a definite extension of the tuberculous lesion in the right upper lobe and pneumothorax was instituted. This was continued throughout 1935 and into 1936. The refills were done at intervals of one or two weeks and from 200 to 600 c.c. of air was introduced at a time. On May 8, 1936, the intrathoracic pressure was -5 to $+4$. Films of the chest after this (Fig. 5) showed complete collapse of the right lung with marked deviation of the mediastinum to the left and a small mediastinal hernia. The patient had only mild discomfort and no air was withdrawn. The lung collapse was complete enough so that no refill was necessary until July 21, 1936, when 300 c.c. of air was introduced. At that time the pressure was -4 to -12.

Case III. J. L. (No 188135). White female, aged eleven. Admitted May 22, 1933, for treatment of incipient tuberculosis. She was given conservative treatment for almost two years.

Physical Examination. She was somewhat undernourished. There was slightly impaired resonance and roughened breath sounds anteriorly and posteriorly over the left apex. Roentgenograms showed shadows of increased density in left apex above the clavicle and at the level of the first interspace. No tubercle bacilli were found at any time.

Bed rest and supportive treatment failed to control the disease. Left pneumothorax was begun on July 20, 1935, and has been continued to the present time. The average size of the refills was 450 c.c. Breathlessness and pain were complained of once each after 400 c.c. of air had been injected on February 21, 1936, and March 23, 1936. The average pneumothorax interval was about eight days. The greatest pressure after any refill was $+17$. Six hundred cubic centimeters of air was introduced September 30, 1935. Final pressure on this date was -7 and $+6$. Films that were made November 13, 1935, showed a mediastinal hernia (Fig. 6). This has persisted until the present time.

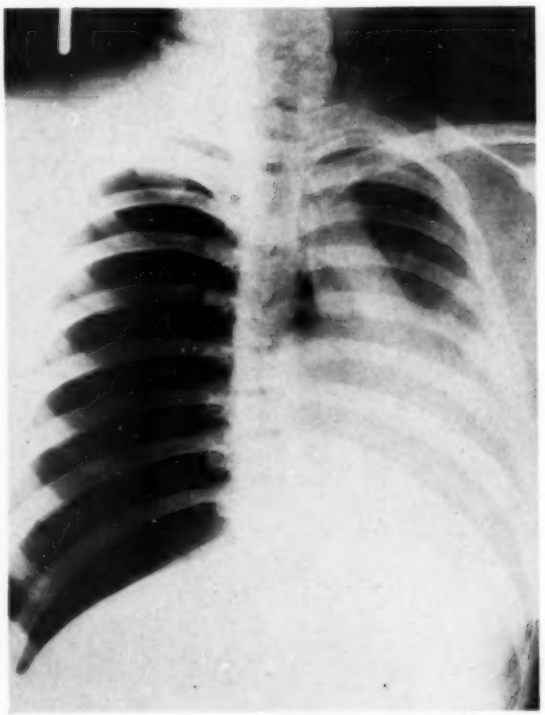

Fig. 5. Case II. Roentgenogram made at height of expiratory phase. There is marked deviation of the mediastinum to the left side with a hernial sac protruding into the left pleural cavity.

CLINICAL SIGNIFICANCE

Dyspnea and pain are usually the most prominent symptoms complained of by a patient with mediastinal hernia. Extreme cyanosis may be present. These symptoms are not characteristic, however, as they may be present in cases of pneumothorax with extreme shifting of the mediastinum, but without hernia. In most instances there are no serious consequences, although there are reports in the literature where death has occurred from spontaneous rupture of the hernial sac into the opposite pleural cavity. This results in bilateral pneumothorax or hydropneumothorax.[4,10]

THERAPY

Treatment will depend upon the urgency of the case at hand. If the symptoms are marked, it may be necessary to remove air from the pleural cavity at once. A reduction in the quantity of air given and a decrease in the frequency of injection will usually cause a disappearance of the hernia. Once the hernia has disappeared, it does not tend to recur and collapse therapy can be carried on with caution.

SUMMARY

1. Mediastinal hernia occasionally develops during the course of collapse therapy by means of artificial pneumothorax.

2. It is more common in young persons where the mediastinum is easily displaced.

3. In most instances, the hernia develops through a weak spot in the upper anterior mediastinum, and extends into the right chest from a left-sided pneumothorax.

4. Hernias are more common when the intrathoracic pressure shows a high positive reading but may occur even with negative pressure.

5. Dyspnea and pain in the chest are the most prominent symptoms complained of by the patient.

6. Treatment consists of aspiration of the pneumothorax cavity which usually brings prompt relief.

7. Cases of death, from rupture of the hernial sac followed by the formation of bilateral pneumothorax or hydropneumothorax, have been reported in the literature.

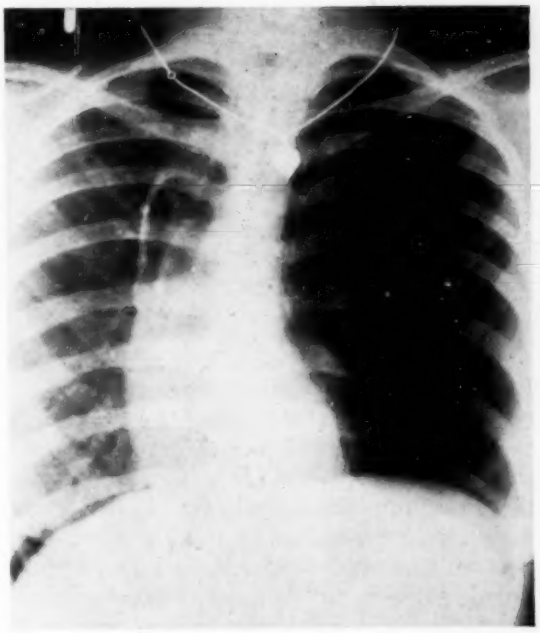

Fig. 6. Case III. Roentgenogram made at height of expiratory phase. The mediastinum deviates to the right side and there is a hernial sac protruding into the right pleural cavity.

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DISCUSSION

Dr. Claude S. Beck, Cleveland, Ohio. Dr. Doub and Dr. Jones have done well in directing our attention to the subject of herniation of the mediastinum. It is surprising, I think, that this lesion does not occur more frequently than the literature would indicate. Perhaps it is with this, as with other things in medicine, that we find what we are looking for. Unquestionably if this condition were looked for, this lesion would be found more commonly.

Two things are necessary for herniation of the mediastinum to develop. One is that the mediastinum be intact and have no opening in it, and the other is that a difference in pressure exist on each side of the mediastinum. In collapse therapy this difference in pressure may be as much as 10 cm. of water. It is difficult to appreciate just how much pressure 10 cm. of water is, and I am sure that the mediastinum must be unable to tolerate this difference in pressure and must herniate quite frequently in its weak spots.

I have under observation at the present time a patient who has, I think, a hernia of the anterior mediastinum, and which followed pneumothorax for tuberculosis. His right lung has been carried well over into his left chest and his heart has gone over with the lung, and both heart and lung have become fixed well out in the left axilla. Curiously enough, these symptoms are all cardiac, and he has no cardiac symptoms when he bends over or when he lies down with his back flexed, but if he extends or hyperextends his back, then he gets circulatory symptoms. We have attempted to correct this condition by bringing the heart back to its normal position. A phrenicectomy has given much relief. I have felt that the circulatory symptoms were due to torsion and angulation of the heart, and experimentally torsion and angulation of the heart can disturb the circulation very markedly, much more markedly than adhesions per se can disturb the circulation. I think the heart is twisted a little, angulated a little, and if we bring it back to the normal position we will correct his symptoms.

PILONIDAL SINUS

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THE roentgenologist is frequently called upon to assist the surgeon in deciding the nature and extent of sinuses and fistulous tracts. Data obtained in this manner are often of considerable aid in the successful eradication of such lesions. In this category is the so-called pilonidal sinus.

This condition was first described by J. M. Warren[10] in 1867. The term pilonidal, meaning hair-nest, was first applied by Hodges[5] in 1880, because of the frequency with which strands of hair are found in this lesion. Since then, many cases have been treated surgically, usually by excision, but without the advantages of roentgenological study. Only a fair degree of success has attended the surgical treatment. About 30 per cent of the cases as cited in the literature reported recurrences, in all probability due to incomplete removal of the entire cyst wall. It is for this reason that I believe that a preoperative roentgenographic study of the pilonidal sinus, injected with a contrast medium, will provide the surgeon with sufficient information to enable him to remove completely the entire sinus and cyst wall, thereby materially increasing the percentage of successes.

THEORIES AS TO PATHOGENESIS

All theories as to the pathogenesis of pilonidal sinus are based upon congenital origin, but differ as to the cause of the embryological defect.

Mallory,[6] after examining the caudal end of six fetuses between the ages of three and six months, concluded that pilonidal sinuses are due to unobliterated portions of the medullary canal during fetal development.

"It would seem from a study of sections from these foetuses that obliteration of the medullary canal takes place at first, and most completely, at the lower end of the sacrum, and extends from this point in both directions. As is well known, the spinal cord at first extends the whole length of the vertebral canal; but as the latter grows the more rapidly in length, the cord rises and the filum terminale is stretched, thus favoring obliteration of the medullary canal at the lower part. The obliteration of the medullary canal between the end of the vertebral canal and the skin apparently frequently takes place in an irregular manner. . . ."

"Undoubtedly the majority of these remnants of the medullary canal become obliterated—only the larger, especially those in which glands and hair are present, persisting as the depressions, sinuses, and cysts of extra-uterine life. . . ."

Weinstein,[12] Stone,[8,9] Bookman,[1] and others, in one way or another, base their theories upon the causation of the pilonidal sinus as embracing the principle of captured ectodermal cells in the subcutaneous tissues and soft parts.

Weinstein believes that the cause is due to a special local down-growth of epithelium originating from the true skin which ends blindly in a sacculated pouch in the soft parts behind the lower sacrum and coccyx.

Stone first thought a peculiar local down-growth of epithelium originating in the true skin occurred, but now thinks that the sinuses are a vestige of the preen glands found in a number of species of birds.

Bookman states that displaced dermal or dermoid cells in the embryo which are lost during the process of fusion in the midline and then assume an abnormal location under the skin, where the products of skin metabolism accumulate to form a cyst, might be the causative factor.

Weeder[11] believes that the condition is due to either of the above factors, or a combination of them. The condition is due to either captured ectodermal cells occurring at any stage during the development of the medullary canal, or faulty obliteration of the medullary canal itself, or a combination of both factors. The included ecto-

dermal cells may be limited to the soft parts, extend to and be caught in the dorsal arches of the vertebrae, or be continuous with or captured in the medullary canal; or the medullary canal during the stage of development may leave unobliterated remnants, either with or without spinal bifida occulta anywhere below the second sacral segment. They may extend to the skin through a sinus, or remain as a cyst. The medullary canal remnant may communicate with a sac of included ectodermal cells and remain as a cyst or reach the outside through a sinus.

In substantiation of his theory, Weeder quotes a case reported by Ripley and Thompson. The patient, a child three and a half months old, developed a staphylococcus meningitis through a pilonidal sinus. At the autopsy it was found that the second sacral arch was deficient. The sinus tract led from the skin to a sac over the second sacral vertebra which contained hair and sebaceous material. The base of the sac communicated with the spinal canal.

Upon the basis of the high percentage of failures reported in the literature following simple excision of the soft parts, Weeder's theory appears to be the most plausible. In those cases in which the sinus reaches bone, Weeder advises the removal of the coccyx, curettement of the articular surface of the sacrum and sacral hiatus and a wide dissection of the tract within the soft parts. He believes that such a program is necessary to effect a cure, as in those cases a part of the cyst wall is contained within the bony parts as unobliterated portions of the medullary canal, and as the embryological medullary canal first disappears at the lower end of the sacrum, the unobliterated portion will be at or below the sacrococcygeal junction.

INCIDENCE AND CLINICAL COURSE

From 20 to 25 per cent of all infants examined at birth, and about 4 per cent of a large group of adults, both male and female, present either a distinct dimple or depression of the skin at the sacrococcygeal region.[3] These are congenital defects of a much lesser degree related to pilonidal sinus. They always remain symptomless. Actual sinus orifices are seen much less frequently. Their exact incidence is unknown. Of a group of 106 cases reported in the literature reaching the surgeon with variable degrees of complaints, 81, or 77 per cent, were males between the ages of four and forty-nine, and 25, or 23 per cent, were females between the ages of eight and thirty-five. The average age when the lesions first became annoying was about nineteen for the whole series. All of the patients were of the white race. Apparently no cases have been found in the negro race.

The lesion, although congenital, is always quiescent during early life, but may become troublesome after adolescence. The tract is lined by poorly developed epithelium, and before the stage of infection there may be some excretion of the products of skin metabolism through the orifice. If the orifice becomes blocked by accumulated epithelial detritus or following an injury, the retained secretions may form a cyst, or more commonly become infected and form an abscess. If this is allowed to rupture spontaneously, as is frequently the case, one or more suppurating fistulous openings adjacent to the original sinus orifice may form and persist for an extended period. If these fistulous openings heal, a secondary abscess may form. This process, in variable degrees, may be repeated a number of times before the patient seeks surgical relief.

CLINICAL DIAGNOSIS

The diagnosis of pilonidal sinus has in the majority of cases been made entirely upon clinical signs and symptoms. Before the stage of infection, the sinus outlet occurs as one or more small round or oval openings in the skin usually about 3 or 4 mm. in diameter, but occasionally large enough to be mistaken for an anus. Such outlets are always located somewhere in the posterior midline of the body near the level of the sacrococcygeal joint, perhaps at the surface of a small depression or

dimple, have smooth edges covered by skin, and are free from granulation tissue. Occasionally, a tuft of hair is seen protruding through the opening. When infected, pus may exude through the orifice, or the region may become swollen and red, painful to the touch and may or may not fluctuate. Secondary discharging fistulous openings may be seen on either side of the midline. A probe inserted into a pilonidal sinus always points toward the sacrococcygeal joint and may extend from 1 to 6 cm. This establishes the diagnosis, but does not give accurate knowledge as to the depth and extent of the crypts which is necessary for complete removal.

ROENTGENOGRAPHIC DIAGNOSIS

Brams[2] reported a case which he studied roentgenographically by injecting the tract with lipiodol and making an exposure with the patient supine. I have had the privilege of studying several such cases. Roentgenograms made in the anteroposterior and lateral projections without the aid of contrast medium are not informative, other than to rule out a possible bone lesion of the lower sacrum and coccyx. However, roentgenograms made after contrasting the rectum, anal canal and sinus, especially in the lateral view, invariably provide an abundance of diagnostic information which can be obtained in no other manner. The rectum is made visible by air inflation, the anal canal by insertion of a hard rubber rectal nozzle, and the sinus by injection of an opaque solution. Using the technique detailed below, the opening, depth and lateral spread of the sinus (cyst) and its various recesses, and their relation to the adjacent osseous system, rectum and anal canal, are readily demonstrated. Such roentgenograms provide advance information as to the extent of involvement, thereby permitting the surgeon to evolve an operative program which would be more certain of effecting a favorable prognosis.

ROENTGENOGRAPHIC TECHNIQUE

The patient is placed horizontally in the position usually assumed in making a lateral exposure of the sacrum and coccyx. The rectum is then distended with air by means of an ordinary atomizer bulb equipped with a hard rubber nozzle attached to a soft rubber tube. The nozzle is left inserted in the rectum during the exposure. Then, under aseptic conditions, the orifice is gently probed to determine its general direction. Iodipin, at body temperature, is then forced into the sinus in the direction found to be most patent by the probe. For this purpose a urethral syringe, having a cone-shaped, semi-soft rubber nozzle and an oversized soft rubber bulb is used. After injection of the opaque solution, the syringe is held firmly against the sinus opening, in order to prevent leakage, until the lateral roentgenogram is made. If more than one opening is present, the others are blocked by exerting pressure upon them. The rectal tube and urethral syringe are then removed, the openings are compressed with a small piece of cotton to prevent leakage. The patient is moved into a supine position so that the anteroposterior roentgenogram can be made. It is very important to prevent any of the opaque material from gaining access to the skin, for its presence there would considerably interfere with accurate interpretation. If leakage should occur, all opaque material on the skin should be thoroughly removed before making the exposures. The Potter-Bucky diaphragm and intensifying screens are employed in making all roentgenograms. Stereograms may be made, but are not essential.

REPORT OF CASES

Case 1. C. A. D., aged twenty, male, white, admitted to the hospital on February 21, 1933, complaining of a discharging sinus of the buttock near the midline. Patient stated that the sinus had been present since December, 1932, and would not heal under ordinary therapy. It was annoying and occasionally tender.

Physical examination showed a discharging sinus at the posterior sacrococcygeal region, with a small, smooth outlined orifice covered by skin. It was not inflamed, nor indurated, but was vaguely tender to pressure.

Roentgen Examination. The sinus was seen to be injected with contrast medium. An irregularly outlined, elongated, blind pocket in the

FIG. 1. Case I. Lateral view of a pilonidal sinus injected with contrast medium and with the syringe held firmly against the sinus opening to prevent leakage. The rectum is distended with air, and the position of the anal canal is indicated by the hard rubber nozzle. Figures 1 and 2 demonstrate the position of the sinus opening, depth and lateral spread of the sinus, its various recesses, and their relation to the adjacent osseous system, rectum and anal canal.

FIG. 3. Case II. Lateral view of injected pilonidal sinus. Findings very similar to those seen in Case I.

FIG. 2. Case I. Anteroposterior view.

FIG. 4. Case II. Anteroposterior view.

soft tissues at the midline was observed behind the sacrococcygeal region. Its measurements were approximately 4 cm. long and 1 cm. wide. There was very little lateral spreading. The sinus was located about 1.5 cm. below the skin surface, and the external opening was close to its upper end. The sacrum and coccyx were not involved and appeared normal. Diagnosis was pilonidal cyst and sinus confined to soft parts (Figs. 1 and 2).

Operation was performed on March 10, 1933, by Dr. Wm. B. Evans. The cyst and sinus were removed by wide dissection of the soft parts and the wound immediately sutured about a rubber drain which was left in situ for several days. The patient made an uneventful recovery. No recurrence was evident after a period of fourteen months. The sac of the cyst contained a quantity of coiled hair.

Case II. S. W., female, white, aged twenty, admitted to the hospital on October 15, 1933, complaining of a discharging fistulous opening in the posterior sacrococcygeal region. There was infiltration and swelling of the soft tissues surrounding the opening. The condition was first noticed five years previously, at which time the patient had had a localized, tender area in the same location. It subsided and remained quiescent until eight weeks previous to admission to the hospital.

Roentgen study of the injected sinus showed findings very similar to that seen in Case 1. The sinus was removed by soft tissue dissection and there has been no recurrence to date (Figs. 3 and 4).

DIFFERENTIAL DIAGNOSIS

A knowledge of the direction, extent and location of the injected sinus is of material aid in the differential diagnosis of pilonidal sinus from discharging fistulous tracts due to anal fistula, ischiorectal abscess, and osteomyelitis of the posterior pelvic bones with openings near the midline.

In anal fistula, the orifice is usually adjacent to the anus, and is surrounded by granulation tissue. The injected tract is usually directed towards the anus. The patient often has evidence of tuberculosis elsewhere.

Ischiorectal abscess causes a large tender swelling at the fold of the buttocks, and is often present without an external opening. When this condition exists and there is an opening, the injected tract is usually directed toward the pelvis and part of it at least is in proximity to the rectum.

Osteomyelitis in the posterior pelvic bones may show demonstrable bone changes on a single plain roentgenogram. Whenever a sinus occurs, however, injection of its tract with a contrast medium will invariably lead to the site of its origin.

CONCLUSIONS

(1) The theories as to the pathogenesis of pilonidal sinus, its incidence, clinical course and methods of diagnosis, are cited.

(2) For a differential diagnosis, a preoperative roentgenographic examination of the injected sinus with a contrast medium is advocated, as it is of invaluable assistance to the surgeon in formulating a correct operative program.

(3) A technique for the roentgenographic examination is described.

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ROENTGEN IRRADIATION AS AN ADJUNCT TO SURGICAL TREATMENT OF PILONIDAL CYST*

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PILONIDAL cysts (sinuses, dimples, or sacrococcygeal dermoids) are found on the dorsum of the sacrum and coccyx as painful swellings, or an indurated, discharging sinus. Usually, there is overgrowth of hair in this region, and frequently hair grows from the mouth of the sinus.

There are many theories concerning their origin. That they are derived in part from the embryologic ectodermal layer is indicated by the epithelial cells lining the walls of the sinuses and cyst cavities. Nails and teeth are not found in true pilonidal cysts. Some authorities believe they are derived from embryonal rests. The theory that it is possibly analogous to the preen gland of certain birds has been advanced by Stone.[5] According to Gross[3] they are "congenital tumors arising from a sebaceous follicle which during development intercepts a small tuft of hair."

Regardless of the various theories of origin, the proper treatment is surgical removal of the cyst and its sinuses. Frequently, however, following apparent complete excision, the wound fails to heal entirely or there is a recurrence of the condition after several weeks.

There are few statistical data concerning the percentage of recurrences, but in a series of 50 cases reported by Cattell and Stoller[2] there were at least 20 that had been operated upon more than once. Anderson reports that 50 per cent of his cases had been operated upon previously. Weeder[6] has pointed out that it is strange that during the past fifty years surgeons of undisputed skill have been embarrassed by having their patients return with discharging sinuses after thorough dissection of the cysts. He believes that frequently a portion of the cyst wall extends into the sacrococcygeal joint and that a recurrence can be prevented only by removal of the coccyx. In 4 cases which he treated by excision of the cyst and the coccyx, none of them showed recurrence after periods varying from several months to a year and a half.

Injection of the sinus tract with methylene blue or with a radiopaque solution has shown many cases in which the cyst wall does not extend into the sacrococcygeal articulation. Undoubtedly, some of these cases fail to heal completely after excision and a draining sinus remains. In this type of case amputation of the coccyx is unnecessary and useless.

Since there are numerous hair follicles in the operative field, hair growth along the sutured skin margins may interfere with complete healing. It was felt that by administering to these patients an epilation dose of roentgen rays over the operative field, the occurrence of persisting postoperative sinuses would be lessened because the wound would have an opportunity to heal completely before hair growth would be reëstablished. The growth of hair along the line of suture prevents primary union and frequently results in a persistent postoperative sinus. Hair follicles in remnants of the cyst wall or sinus would also be destroyed. The effect of irradiation on any remaining portion of the cyst wall itself cannot be estimated. Pilonidal cysts are usually infected. The beneficial effect of irradiation on infected tissues has been well established. If a portion of an infected cyst wall remains, it is reasonable to assume that clearing up the infection will facilitate healing of the wound. One of the patients treated had a persistent, infected, draining sinus of almost two months' duration following operation, when she was treated with roentgen rays. In three weeks discharge had entirely ceased, the wound

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was completely healed and she has been free from discharge since then. In another patient, drainage had persisted more than nine months after operation before he was irradiated. In less than two weeks the discharge had stopped. A second operation was not performed. The other 4 patients treated show no evidence of recurrence of the lesion. Of course, the study has not been carried out sufficiently long or extensively enough to draw any positive conclusions. The results to date, however, have been so encouraging that preoperative irradiation in pilonidal cysts has become routine procedure on one of the surgical services in Jefferson Hospital.

Table I

RESULTS

Case I. Completely healed. No recurrence six months after operation. Hair growth not re-established.

Case II. No recurrence in six months. No return of hair over the area treated.

Case III. No recurrence. Hair absent after six months.

Case IV. Drainage stopped two weeks after treatment. Epilation complete one month after treatment. Did not return for further observation.

Case V. Three weeks after treatment discharge stopped. No drainage for four months.

Case VI. Healed. No evidence of recurrence in three months.

The technique has been varied somewhat, but sufficient radiation was administered in each instance to produce epilation in the area treated. Various dosages ranging from 386 to 579 roentgens were used. Superficial irradiation at 130 kv. and 5 ma. was employed in all instances. The treatment was delivered to the sacrococcygeal area through a 9×11 cm. field, at a skin-focal spot distance of 12 inches. In the first case treated, 4 mm. Al filtration was used; no filter was employed in the other 5 cases.

Table II

DOSAGE

	Kv.	Ma.	Filter	r
Case I	130	5	4 mm. Al	484
Case II	130	5	none	484
Case III	130	5	none	484
Case IV	130	5	none	386
Case V	130	5	none	486
Case VI	130	5	none	579

Time of irradiation in reference to the time of operation also varied. One case was treated twenty-two days before his second operation; one two days; one one day and one two hours preoperatively. The other two were treated postoperatively; one forty-six days and the other over nine months after operation.

Table III

TIME OF TREATMENT RELATIVE TO TIME OF OPERATION

Case I. 22 days before second operation
Case II. 1 day before operation
Case III. 2 days before operation
Case IV. 281 days after operation
Case V. 56 days after operation
Case VI. 2 hours before operation

The sinuses in all of these cases were carefully injected with methylene blue at the time of operation. The dye did not invade the sacrococcygeal articulation in any of them.

Six patients were irradiated. All of them were young adults and all but one were males. This ratio is essentially the same as that found by Anderson. The average age was 20.6 years.

Table IV

INCIDENCE

		Sex	Age
Case I	R. S.	Male	22 yr.
Case II	J. C.	Male	19 yr.
Case III	A. S.	Male	21 yr.
Case IV	S. A.	Male	20 yr.
Case V	E. S.	Female	23 yr.
Case VI	V. R.	Male	19 yr.

Case I. R. S., male, clerk, aged twenty-two. He had been operated upon in 1933 for pilonidal cyst. A discharging sinus reappeared about four months later. On September 3, 1934, he was given 484 r through a 9×11 cm. field over the sacral area. The following factors were used: 130 kv.; 5 ma.; 11 min.; 4 mm. Al filter; 12 inch distance. The recurrent cyst was again excised September 25, 1934 (Lahey method). At this time complete epilation had occurred. The wound healed uneventfully and at the present time shows no evidence of recurrence.

CASE II. J. C., male, tailor, aged nineteen. Onset January, 1934, with swelling over the sacrum which broke down and discharged a thin, purulent material. He was given 484 r on September 27, 1934: 134 kv.; 5 ma.; 2½ min.; no filter; 12 inch distance. The patient was operated upon September 28, 1934. Progress was uneventful. Hair had appeared on the area treated at the time of the last examination, March 14, 1935. There was no evidence of recurrence.

CASE III. A. S., male, farmer, aged twenty-one. In May, 1934, he noticed a painful, draining sinus over the lower end of the sacrum. On September 27, 1934 this area was given 484 r: 130 kv.; 5 ma.; 2½ min.; no filter; 12 inch distance. S.E.D.—3.1 min. The cyst was removed September 29, 1934, and on April 3, 1935, the area treated showed no evidence of hair growth. The wound had healed completely.

CASE IV. S. A., male, unemployed, aged twenty. Onset January, 1934, with a small mass over the base of the spine which broke down and discharged pus. Cyst was excised March 13, 1934. The wound was clean on discharge from the hospital but it failed to heal entirely and has been draining since then. The patient was seen in the Surgical Follow-Up Clinic on December 19, 1934, at which time there was a small sinus at the site of operation from which exuded a thin, serous discharge. Several hairs protruded from the sinus. He was given 386 r of unfiltered radiation that same day. One month later the area treated was free from hair. He said that drainage had entirely stopped two weeks after treatment. He did not return for further observation.

CASE V. E. S., female, dental hygienist, aged twenty-three. Onset July 26, 1934, with painful swelling over base of sacrum. Swelling broke down and discharged some liquid material. Examination revealed an inflamed, indurated area over the base of the spine, with a small draining sinus containing many hairs. The cyst was removed surgically on October 22, 1934. The wound did not heal entirely and patient was given 486 r of unfiltered radiation on December 17, 1934. On January 8, 1935, a small dimple persisted at the lower end of the scar. There was no evidence of discharge, but the patient said that there was a small amount present at times. Hair growth had not returned at that time. Two days later the discharge had stopped entirely and the sinus closed over. On April 7, 1935, the wound was well healed and clean. There was no discharge. There was a growth of thin, soft hair beginning to appear over the treated area.

CASE VI. V. R., male, tailor, aged nineteen. In May, 1934, the patient thought he had developed a boil over the lower end of his spine. However, the swollen area was not painful. This area gradually grew larger and he noticed another smaller, swollen area close to the first one. In November, 1934, these areas became quite painful and one month later started draining creamy pus from two openings. Upon admission on January 13, 1935, he had two small openings in the skin over the sacrum, about 8 cm. above the anus. A thin serous discharge was present. To the right of this region there was a mass of exuberant tissue which discharged a seropurulent material from two other sinuses. The area was quite hairy.

The following day he was given 579 r of superficial, unfiltered radiation through a 9×11 cm. portal. Two hours later, following the injection of the sinuses, the cyst was excised. The cyst did not extend into the sacrococcygeal joint. The wound was closed, with drainage for forty-eight hours. His recovery was uneventful and upon discharge on January 29, 1935, there was only a small amount of drainage present.

He returned April 5, 1935. His skin was tanned; epilation remained. He said that he had had no discharge from his wound. There was just a suggestion of a small open area at the lower end of the incision. It would only admit the tip of a small probe. There was no evidence of any drainage.

CONCLUSIONS

1. Six cases of pilonidal cyst treated with roentgen radiation are reported. Treatment was administered preoperatively in four and postoperatively in two cases.

2. This procedure is not intended to supplant surgery but to serve as an adjunct in the treatment of pilonidal cyst.

3. The dose in roentgens varied, the average being 486 r. Enough radiation was

given to produce epilation over the sacro-coccygeal area. The object was to prevent hair growth from interfering with healing, and to control infection.

4. The amount of radiation given was not sufficient to delay healing of the incision.

5. Sufficient time has not elapsed in this study to prove the efficacy of this form of treatment. The results to date have been encouraging enough to warrant continued investigation.

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THE MEASUREMENT OF THE IONIZATION PRODUCED IN AIR BY GAMMA RAYS

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GENERAL INTRODUCTION

THE problem of measuring gamma rays by ionization which they produce in air has been studied in our laboratory from different aspects. On the one hand, several attempts have been made to make the measurements under conditions approaching those which might be expected to fulfill the requirements of the definition of the roentgen. On the other hand, the application of the results to the problem of dosage in radium therapy has been investigated by physical and biological experiments. We have reached the conclusion that it is extremely difficult to measure gamma rays in roentgens by any method we have tried, with the possible exception of the thimble chamber method. Whether the latter really fulfills the requirements of the definition of the roentgen is questionable, but if there were an impellent reason for adopting today a method of measuring gamma rays in roentgens, this would be the method of choice. As a matter of fact, not only is there no such urgent need, but adopting this method would lead to serious complications of a practical as well as theoretical nature.

The ultimate aim of the use of a common unit of dosage in radium and roentgen therapy is the correlation of tissue dose administered and biological effects produced. The ideal situation would be one in which, other conditions being equal, the same dose of roentgen rays or gamma rays would produce the same biological effect. Experiments show that this is not the case in general, no matter what fixed unit of dosage is chosen. Furthermore, if a conventional thimble chamber method is adopted for the determination of the "effective gamma-ray emission" of radium, in general the same dose of *gamma rays* expressed in roentgens does not produce the same biological effect. This is particularly true under the treatment conditions ordinarily employed in radium therapy, which makes the difficulty of more than academic interest.

A direct correlation between dose and effect in a restricted wave length region becomes possible and practical when the dose is measured by the ionization which the radiation produces in air *under the conditions obtaining in the irradiated tissues.* A unit based on these premises affords the simplest correlation between dose and effect, not only for roentgen rays and gamma rays, but for all types of ionizing radiation. This suggestion was made by one of us at the Fourth International Congress of Radiology, Zürich, July, 1934. Further experimentation and new developments in neutron research (biological effects) support this view.

I. EXPERIMENTS WITH OPEN AIR IONIZATION CHAMBERS

Measurements of gamma rays with a parallel-plate ionization chamber were first made by us[4] in 1930–1931. Properly collimated gamma-ray beams were obtained by using short capillary glass tubes containing radon placed at the apices of long conical apertures in a lead block. The ionization chamber used was one which had been designed for roentgen-ray measurements[2] and had a maximum plate separation of 24 cm. The vacuum tube current measuring device available at the time was not sensitive enough to permit the use of gamma-ray beams of very small solid angle and this, coupled with the limitation of plate separation, compelled us to place the ionization chamber close to the mouth of the collimating cone. The distance from

the edge of the conical diaphragm to the center of the collecting electrode was 37.5 cm. The end of the chamber housing, with an opening 10 cm. in diameter, was at 11 cm. from the limiting diaphragm. With this setup it was found that separating the chamber plates beyond 15 cm. did not increase appreciably the ionization current. It was assumed, therefore, that the requirement of utilizing all the secondary electrons, in the definition of the roentgen, had been fulfilled. We thought at the time that the distance between the collimating diaphragm and the collecting electrode was perhaps too short and that errors might be introduced due to: (1) the large proportion of secondary electrons produced in the lead cone which could reach the volume in which the ionization was measured; (2) lack of equilibrium between gamma rays and secondary electrons. The first would tend to make the ionization reading too high, while the latter would make it too low. Tests were made as follows: A piece of bakelite, 6 mm. thick, was placed over the mouth of the lead cone to remove the excess secondary electrons produced in the lead, and at the same time provide the proper complement of secondary electrons which would be expected from an equivalent thickness of air. It was found that, other conditions remaining the same, the presence of the bakelite decreased the ionization reading in approximately the same ratio as one would expect from the attenuation of gamma rays. The second test consisted in placing the ionization chamber at a greater distance from the diaphragm. The ionization reading was also lower in this case, but the result was not unexpected in view of the increased cross-section of the beam at the level of the collecting electrode and other geometrical limitations. It was therefore decided to build a much larger ionization chamber for a more thorough investigation of the problem. That further study was necessary was also indicated by the great difference in results obtained with different methods of measurement. The gamma-ray emission measured with our setup was found to be 36 r/min. per gram at a distance of 1 cm. from a point source of

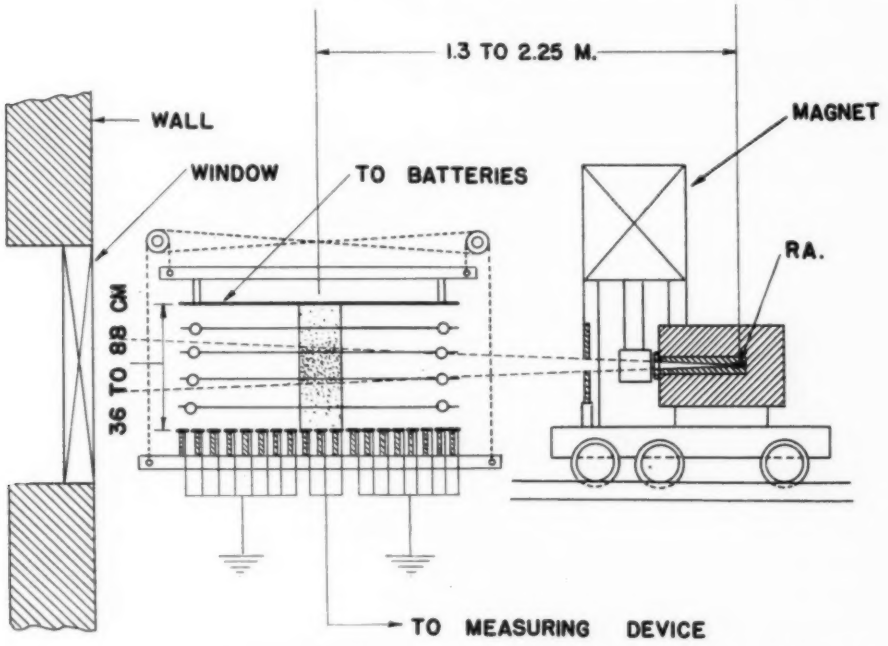

Fig. 1. Experimental setup, showing use of parallel plate ionization chamber with collimated beam of gamma rays.

radium filtered by 0.5 mm. of platinum. (For the sake of brevity we shall refer to this quantity as the effective gamma-ray emission of radium.) The corresponding value obtained by measurements with a small graphite spherical chamber was 137 r/min./gram.[4]

Figure 1 shows a later (1931–1933) experimental setup drawn to scale for one particular set of conditions. To obtain well-defined beams of radiation the same lead block and cones were used as in the 1931 experiments. A strong electromagnet was placed at the mouth of the cones to deflect the secondary beta rays behind a lead diaphragm somewhat larger in diameter than the cross-section of the gamma-ray beam at this point. Both the lead block and the magnet were mounted on the same carriage running on a track so that the distance between the source and the center of the chamber could be varied readily from 130 cm. to a maximum of about 225 cm. By removing the electromagnet, a distance of 1 meter could also be used. The source was always at the effective apex of lead cones 22.5 cm. long. Provisions were made for an intermediate diaphragm of lead or other material to be placed in front of the chamber. (This is not shown in the figure.) The ionization chamber consisted of two parallel plates of aluminum about 100×150 cm., mounted on two iron frames by suitable insulators. These frames and plates were suspended from the ceiling by a system of sprockets and chains in such a way that one plate acted as the counterweight for the other and the spacing between the two could be varied readily from zero to a maximum of 88 cm., while maintaining the radiation beam at equal distances from the plates. The upper plate was made of one solid sheet of aluminum while the lower one was made up of 19 aluminum strips 5.7 cm. wide, individually insulated and separated from one another by air gaps of 1 mm. Each one or a number of these strips could be used as collecting electrode. It should be noted in this connection that the collecting electrode, made up of one or more of the aluminum strips, extended over the full width of the chamber (100 cm.). It is important that the dimension of the collecting electrode at right angles to the radiation beam be at least as large as the plate separation. If this is not the case, the advantage of the large plate separation is partly lost, since some of the ions are carried to the guard plates and do not register on the collecting electrode.

On account of the great plate separation desired, provision was made to insure a uniform electrostatic field in the useful volume of the chamber, by means of thin rods and wires in the periphery, properly spaced and connected to the appropriate taps of the battery supplying the voltage to the upper plate. This scheme had been found satisfactory in our laboratory in connection with a smaller chamber[2] and has been investigated thoroughly by Taylor.[17] In order to avoid readjustment of these equipotential conductors for each plate separation, they were suspended and interconnected in their proper positions by means of rubber bands, so that for any plate separation beyond a certain minimum the distance between any two adjacent conductors remained the same fraction (i.e. 1/5) of the distance between the plates. Large wire gauze screens (200×300 cm.) were provided to shield the chamber on four sides from electrostatic disturbances. The current measuring device was of the vacuum tube type previously described,[3,4] but of higher sensitivity. The design of this chamber is more elaborate than subsequent work proved it to be necessary, but at the time it was constructed (1931) it was intended primarily for an extensive series of experiments with 900 kv. roentgen rays. Incidentally, the limit for its size was set by the dimensions of the lead-lined room in which it was to be housed for the roentgen-ray measurements.

Since in our previous experiments with a smaller open air chamber placed close to the mouth of the lead cones, we had found that further separation of the plates beyond 15 cm. did not increase appreciably

the ionization current, it was evident that the value of the effective gamma-ray emission thus found (36 r/min./gram) could not be increased materially by the mere increase of plate separation. Furthermore, the well-known fact, that the fastest recoil beta particles are emitted initially in the forward direction and are then scattered, led to the conclusion that the source of radiation and the limiting diaphragm should be placed far from the collecting electrode of the chamber. Accordingly, different source to center of electrode distances were used in the experiments. Cones of three different solid angles were also used. With the source at a distance of 2 meters from the center of the collecting electrode, the cross-section diameters of the geometric beams at this point were 22.7, 16.2, 10.6 cm. for the large, medium and small cones, respectively.

The results of one set of measurements made (July, 1933) with the medium cone and different source-to-center distances are shown by the solid curves in Figure 2. The ionization is expressed in terms of the effective gamma-ray emission (at 1 cm.) simply for reference purposes, although there is no justification for the use of the roentgen in this connection. It will be seen that as the plate separation increases the ionization also increases, and does not reach a maximum within the range investi-

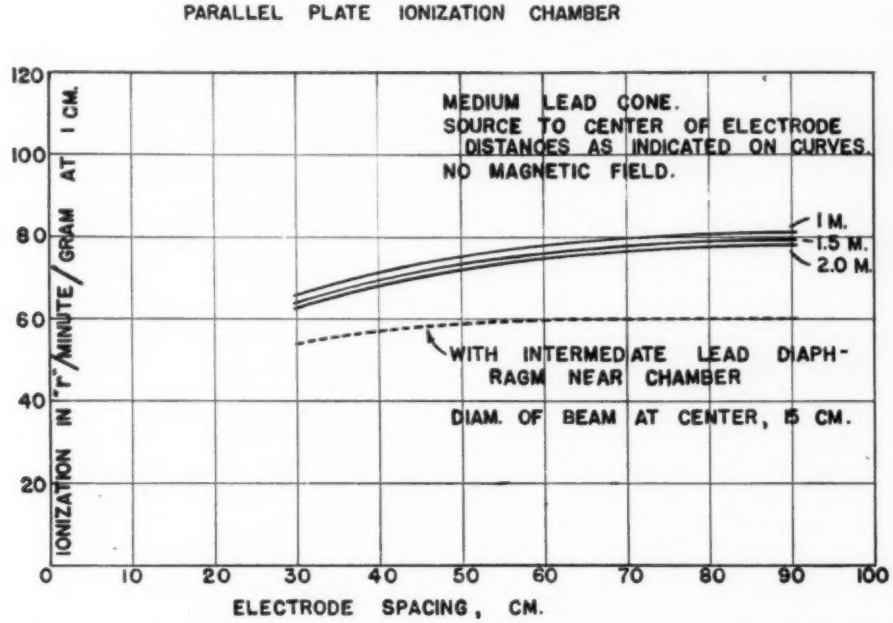

Fig. 2. Curves showing results obtained with parallel plate ionization chamber as functions of different electrode spacings and different source to chamber distances.

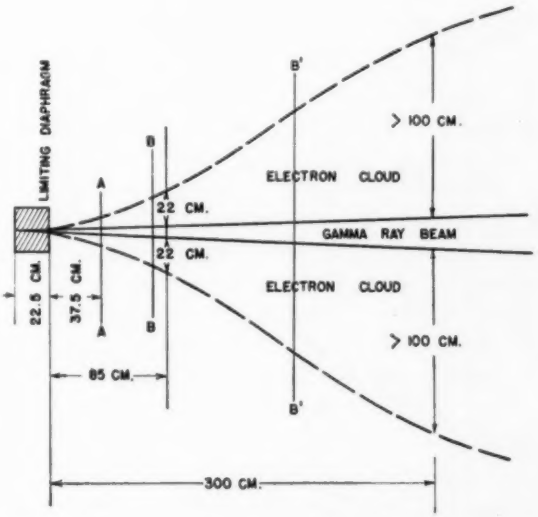

Fig. 3. Approximate outline of the electron cloud surrounding a collimated beam of gamma rays.

gated. The ionization measured by the chamber decreases somewhat as the distance between the limiting diaphragm and the chamber increases.

The explanation of the results shown in Figure 2 is obvious when one considers the distribution of the recoil beta rays in a narrow beam of gamma rays. It is shown schematically in Figure 3. Assuming that the secondary beta rays emerging from the lead cone are removed by an electromagnet, those formed in the air, from that point on, are distributed about the gamma-ray beam substantially within the envelope indicated by the dotted lines. The cross-section of this envelope increases with the distance from the mouth of the cone and finally reaches a value which remains constant, provided allowance is made for the enlarging cross-section of the gamma-ray beam itself. The reason for the small cross-section of the "electron cloud" near the lead cone is that the probability of scattering at large angles is small for fast beta particles. Therefore most of them tend to travel in the general direction of the gamma-ray beam and do not wander far beyond the confines of the beam until they have suffered many encounters in traversing a large thickness of air. There are, undoubtedly, some secondary electrons outside of the volume indicated by the dotted lines near the lead cone, but their number is insignificant in comparison. Accordingly, the plate separation of a standard chamber placed in this region need not be large to catch all the ions. This was the case with our small chamber placed in the region *A-A* in the 1931 experiments (even though no magnetic field was used to remove the secondary electrons at the mouth of the cone). The results shown in Figure 2 were obtained with a much larger chamber placed in the relative positions *B-B* to *B'-B'*. In this case the electron cloud was of larger cross-section than the maximum plate separation of 88 cm., even when the center of the chamber was as close as 77.5 cm. to the edge of the limiting diaphragm (which is really the controlling distance).

The following subsidiary experiment substantiates these views. A sheet of lead 1.5 mm. thick, with a circular hole just large enough to allow the gamma-ray beam to pass through unimpeded, was placed in front of the chamber. The proper position and size of the hole with respect to the gamma-ray beam were determined by means of photographic films. A clearance of 5 mm. around the periphery of the beam was allowed, in order to make sure that the gamma-rays did not strike the lead. Under these conditions it was found that no further increase in ionization current occurred with an increase of electrode separation beyond 60 cm. This is shown by the dotted curve in Figure 2. The insertion of the thin lead diaphragm in front of the chamber amounted in effect to a shifting of the limiting diaphragm to this position. The lead sheet stopped practically all beta particles outside of the confines of the gamma-ray beam itself, which otherwise would have entered the chamber. The distance from this diaphragm to the distal plane bounding the volume from which ions were able to reach the collecting electrode was not large enough to make the cross-section of the electron cloud greater than 60 cm. at this level. Making allowances for the diameter of the gamma-ray beam at the same level (15 cm.) and neglecting the influence of the fairly large cross-section of the gamma-ray beam and intermediate diaphragm opening, it is found that at a distance of 85 cm. (taking the center of the collecting electrode for convenience) from a limiting diaphragm, the electron cloud extends to approximately 22 cm. beyond the cross-section of the gamma-ray beam. From the 1931 experiments with the smaller chamber it is found by the same process that at a distance of 37.5 cm. from the limiting diaphragm the electron cloud surrounding the gamma-ray beam has a thickness of roughly 5 cm.—a better approximation being unwarranted owing to the presence of a rather small opening at the end of the chamber on the incidence side. The ap-

proximate outline of the electron cloud in Figure 3 was constructed from the results of these experiments and others which will be described later.

It is obvious from the foregoing that, in order to measure gamma rays in roentgens with a parallel plate chamber, the latter must have an ion collecting cross-section much larger than 100×88 cm. (as used by us) and that the collecting electrode must be at a considerable distance from the edge of the collimating diaphragm or any intermediate diaphragm. The criterion of no increase in ionization current with electrode separation beyond a certain point is not sufficient unless the distance from the last diaphragm to the collecting electrode is greater than the atmospheric air distance which the gamma-ray beam must traverse to attain equilibrium with its secondary electrons.

Applying the plate separation criterion alone, one obtains different values for the effective gamma-ray emission of radium, depending on the distance from the collimating diaphragm at which the measurement was made. Thus we obtained a value of 36 r/min./gram in 1931 with an experimental distance of 37.5 cm. In the experiments described here with the intermediate diaphragm 85 cm. ahead of the center of the collecting electrode, the corresponding value is 60 r/min./gram. On the other hand, without the intermediate diaphragm, in which case the travel of secondary electrons was not impeded (except by the chamber itself), the ionization current continued to increase with increasing electrode separation. The largest value obtained under the conditions shown in Figure 2 was 81 r/min./gram. It is evident that a further increase in ionization current would have occurred if the electrodes could have been separated farther, in spite of the short distance between the lead cone and the collecting electrode used in this case. However, one should bear in mind in this connection that, owing to the short distance used, some secondary electrons liberated in the lead cone may have contributed to the ionization measured by the chamber. Tests carried out at somewhat greater distances (owing to the size of the magnet) showed that a strong magnetic field had no influence on the ionization current. It is hardly necessary to add that one is not justified in the use of the roentgen to express the effective gamma-ray emission of radium determined under these conditions.

At this point it may be well to discuss some results reported by other investigators. Mayneord and Roberts,[11] using an air chamber somewhat bigger than the one first used by us, obtained a value of 51 r/min./gram for the effective gamma-ray emission. With Figure 3 in mind, it is probable that these authors used a collimating diaphragm to collecting electrode distance greater than we used in 1930–1931 and not as long as the distances used in the experiments described above. As already pointed out, the presence of obstacles in the path of the secondary beta rays traveling towards the chamber has a considerable influence on the ionization current. This may account for the fact that these authors obtained substantially the same result with (unstated) different chamber distances.*

At the Fourth International Congress of Radiology, Zürich, 1934, Kaye and Binks[8] reported on their experiments with large air chambers, the largest being comparable in size to the one used by us. These authors summarized their results as follows:

"The measurements so far made show that a sufficiently large free air chamber gives results equivalent to a value of the order of 3.5 r" (=58.3 r/min./gram in our notation). "This value was found to be unaffected by (a) increasing the size of the chamber, (b) increasing the electrode separation above a minimun which allows a clearance of about 10 cm. beyond the periphery of the gamma ray beam, (c) increasing the size of the measuring electrode, (d) increasing the distance of the radium (from 4 to 7 metres), ... It appears therefore

* It is possible that our low value of 1931 was partly due to the presence of the end cover of the chamber in which the opening of 10 cm. diameter may have acted as an intermediate diaphragm.

that in a free air chamber of adequate dimensions, the electronic transfer across the air boundaries of the measured volume is fully compensated and that the definition of the roentgen is satisfied."

In the light of our experimental results given here and presented by one of us at the Fourth International Congress of Radiology, it is difficult to account for Kaye and Binks's results. One of the present writers (G. F.) saw the air chamber at the National Physical Laboratory in 1934 and discussed the problem with Kaye and Binks. It was evident that the large chamber used by these authors at that time was not designed properly, and undoubtedly this accounts for their peculiar results. Since they used radium distances of 4 to 7 meters, they should have obtained a value of the effective gamma-ray emission much higher than 58.3 r/min./gram with a chamber 1×2 meters and a plate separation of 1 meter. It will be recalled that with a somewhat smaller chamber we obtained a value of 81 r/min./gram and that if our chamber had allowed a plate separation greater than 88 cm. we would have obtained a still larger value (see Fig. 2). In view of the discrepancy between our results and those of Kaye and Binks, they[9] designed a much larger and better parallel plate chamber and published some preliminary results in 1936. In this case, they found that the value of the effective gamma-ray emission is influenced markedly by the size of the air chamber. They estimate it to be between 117 and 133 r/min./gram.

Theoretically the specific gamma-ray emission of radium *in roentgens* should have but one value. Experimentally, values obtained by the same method of measurement (free air chamber) vary from 36 to 133 r/min./gram. Obviously this means that the experimental conditions have not been correct and, strictly speaking, the results should not be expressed in roentgens at all. We agree with Kaye and Binks that parallel plate ionization chamber measurements of gamma rays involve great difficulties and in fact we abandoned the method after our 1933 experiences.* However, we used later an equivalent but simpler method in order to get a better idea of the spread of the electron cloud associated with a gamma-ray beam.

For many years we have used for roentgen-ray measurements a type of ionization chamber which has the essential characteristics of the standard air chamber and some additional advantages. The chamber consists of three parallel "plates" made up of very light silk mesh stretched on appropriate frames. The silk is soaked in India ink to give it the desired conductivity. Silk threads† stretched in a plane serve the same purpose, provided the spacing between adjacent threads is less than the separation between the planes, and some other conditions are met, which are of no importance in the present case. The middle plate forms the collecting electrode while the outer two are charged to the voltage required for saturation current. The beam of radiation to be measured passes through the chamber normal to the plates. In a properly designed chamber of this type, the volume in which the ionization is measured is determined by the area of the diaphragm and the distance between the two outer electrodes. In order to utilize all the secondary electrons the silk plates should be at least as large as the corresponding plate separation in the usual standard air chamber. The mesh type of chamber has the advantages of simplicity, compactness and low saturation voltage. In gamma-ray measurements of the kind discussed here, where the natural ionization of the air is comparable to that of the radiation to be measured, the advantage of a fixed small distance between the electrodes is a great convenience.

The dimensions of the chamber were set in our case by space limitations in the room where the experiments were performed. The plates were 2.2×2.2 meters, made up of silk chiffon. The spacing between plates

* Other reasons will be apparent later.

† Aluminum wires less than 0.04 mm. in diameter have been found to be suitable and more permanent.

was adjustable, but one of 23.8 cm. between the two outer plates was used in the experiments. The same means of beam collimation were used as in our previous work. The distance between source and chamber could be increased to a maximum of 3 meters. In order to get an estimate of the extent of the electron cloud beyond the confines of the gamma-ray beam, the following procedure was adopted: A sheet of cardboard 3 to 4 mm. thick and 2×2 meters was placed directly in front of the ionization chamber. With the source at a distance of 3 meters from the center of the chamber, the collimated beam of gamma rays was 34.5 cm. in diameter at the level of the cardboard. A hole slightly bigger than this was cut through the screen to allow the gamma rays to pass through, while the cardboard would stop most if not all of the secondary electrons outside of the beam. The ionization current in the chamber was measured under these conditions. The hole in the cardboard screen was then enlarged and another ionization reading taken. The procedure was repeated until no screen remained in front of the chamber. The results (obtained in March, 1936) are shown graphically by the solid curve in Figure 4. The 100 per cent point was chosen for the measurement in which the hole in the cardboard was slightly larger than the gamma-ray beam. It will be seen that the ionization increases steadily as the opening is enlarged and that it does not reach a maximum within the limits set by the size of the chamber (2.2×2.2 m.). It should be noted that the experimental curve is subject to the limitations of the setup. The gamma-ray beam had a large cross-section at the level of the cardboard and therefore relatively more secondary electrons passed through the opening and reached the ionization chamber than would have been the case with a much smaller beam. This effect is most marked in the first part of the curve. At the other end of the curve, however, the effect of the large gamma-ray beam is in the opposite direction and the experimental value is probably lower than it would have been with a narrow beam. The thickness of air traversed by the rays from the cardboard screen to the back "wall" of the ionization chamber influenced the experimental results in about the same way also. Accordingly, if the measurements had been made with a very narrow beam of gamma rays

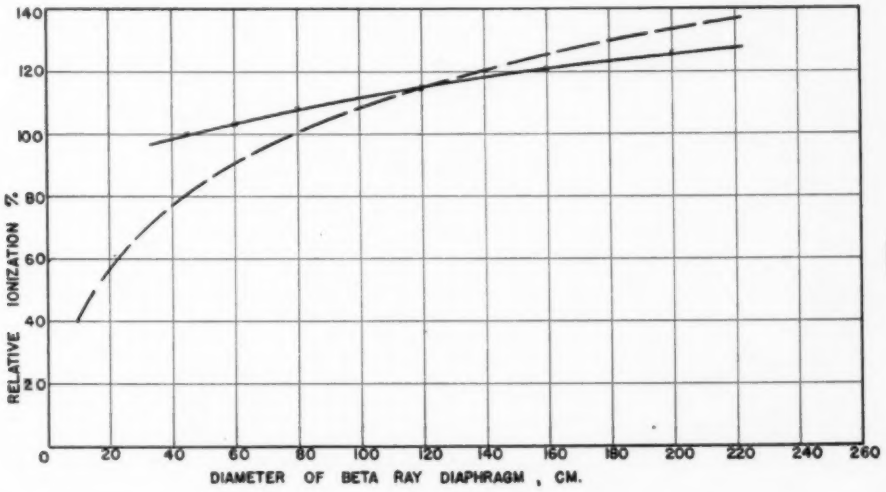

Fig. 4. Curves showing relation between ionization and size of beta-ray diaphragm placed in front of an ionization chamber of the mesh type. Solid curve: experimental results with wide beam. Broken curve: results to be expected with narrow beam.

and a very thin ionization chamber close to the cardboard screen, the relative increase in ionization with increase in the diameter of the beta-ray diaphragm would have been approximately as shown by the dotted curve in Figure 4. The important conclusion to be drawn from this experiment is that, at a distance of 3 meters from the collimating diaphragm, the electron cloud of a gamma-ray beam extends more than 1 meter beyond the periphery of the beam. Therefore, a very large air chamber (at a long distance from the source) must be used in order to utilize all the secondary electrons of a gamma-ray beam. An air chamber of the silk mesh type is much more suitable for this work than the conventional standard chamber, but nevertheless the experimental difficulties are very great. It has long been our opinion that it is a waste of time and effort to attempt to measure gamma rays in roentgens by means of an air chamber. It is of little interest that the largest value of the specific gamma-ray emission, obtained with this chamber, is 106 r/min./gram since the conditions of the definition of the roentgen, obviously, were not fulfilled. We have presented here a very small part of the data obtained in the measurement of gamma rays with air chambers since it is of no practical value. It may be well to mention, however, that removing the secondary beta rays by means of a strong electromagnet at the mouth of the lead collimator has no influence on the ionization current, when the air chamber is at a greater distance than 2 meters from the collimator. This shows that the secondary beta rays which reach the chamber originate in a fairly short column of air. An exhaustive study of this point was not made, but the following experiment (performed for an entirely different purpose) is very illuminating in this connection.

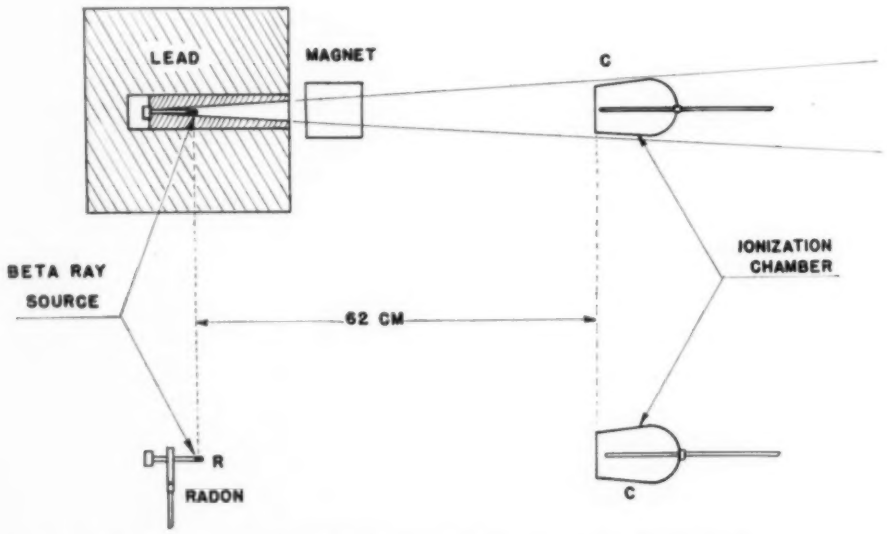

FIG. 5. Effect of canalization of beta rays on ionization at a distance from the source.

In Figure 5, *R* is a thin-walled glass tube containing radon, which served as a source of high speed beta rays (and, unavoidably, gamma rays). At a distance of 62 cm. from the source was placed an ionization chamber made of thin paper with a front wall of silk netting. Under these conditions the ionization current produced in the chamber may be taken to be 100 arbitrary units for purposes of comparison. The same beta-ray source placed in a lead cone as shown in the upper part of the figure, with the ionization chamber properly aligned and again at a distance of 62 cm., produced a current of only 4.8 units. The marked de-

crease in the ionization current shows that most of the beta particles, which originally reached the chamber, were either entrapped by the lead canal, or wandered out of the narrow cone subtended by the chamber. The scattering of beta rays out of the geometrical beam is even more marked than the above figures indicate, since some ionization was produced by gamma rays. Thus, after placing a strong electromagnet at the mouth of the lead cone to remove the emergent beta rays, the residual ionization due to the gamma rays was found to be 2.07 units. Making allowances for this, we find that the ionization in the chamber due to the primary beta rays alone dropped to 2.8 per cent when the source was placed in the lead cone. This gives a striking indication of the effectiveness of the scattering process in deflecting secondary electrons out of the confines of a very narrow beam of gamma rays. We wish to call attention to the fact that in this experiment the distance between the beta-ray source and the ionization chamber was considerable (62 cm.) so that beta rays which underwent small angular deflections at each encounter had a good chance to get out of the geometrical beam. Similarly, when the lead cone was not present, even some beta rays which were emitted initially in the opposite direction could eventually reach the ionization chamber by repeated small angle scattering. (This is a very important point to which we shall return later.) Had the distance been shorter, the effect probably would not have been so marked. Lack of time has prevented our making a more extensive study of this interesting problem.

Before leaving the subject, it may be well to discuss a point of theoretical interest. It is generally known that the "depth doses" for radium bombs determined with a small ionization chamber in a water phantom do not depart much from the inverse square of the distance relation. In other words, the attenuation of the gamma rays in several centimeters of water appears to be negligibly small. This means that there must be considerable "degradation" of the gamma rays whereby the energy of the scattered radiation becomes more readily available to produce ionization. Gray[6] has shown that the ionization produced in a small air cavity in a large block of aluminum at some distance from a gamma-ray source, also within the aluminum block, is largely due to scattered radiation. While the thickness of material of low atomic number but high density compared to atmospheric air which brings this about is considerable, one may well suspect that the scattered gamma rays perhaps contribute appreciably to the ionization measured by an open air chamber under the conditions imposed by the definition of the roentgen regarding the utilization of the secondary electrons. In other words, when the ionization chamber is large enough and is at a sufficient distance from the collimating diaphragm to bring about the utilization of all the secondary electrons, is the ionization produced in the same chamber by the scattered gamma rays negligible? If it is not, then, strictly speaking, the measurement cannot be expressed in roentgens, since by implication the definition of the roentgen demands the exclusion of the scattered radiation. It is questionable, therefore, whether gamma rays can be *actually measured* in roentgens by means of an open air chamber. The problem is very difficult to investigate either experimentally or by theoretical calculations. The best that can be done at this time is to make some rough approximation. An attempt may be made in the following way.

Let Figure 6 represent the conditions under which gamma rays could be measured in roentgens by means of an air chamber of the silk mesh type. The diameter of the chamber AB and the distance D would have to be such as would bring about electronic compensation, whereby an amount of energy equal to that imparted to the secondary electrons by the gamma rays in the shaded volume is delivered to the entire air volume of the chamber and

is utilized in producing ions, through the passage of other secondary electrons liberated within the confines of the gamma-ray beam. The distance D should be equal to the range of the fastest secondary beta particles, and the diameter AB should be approximately twice D. The thickness t of the air volume in which the ionization is measured is not critical.

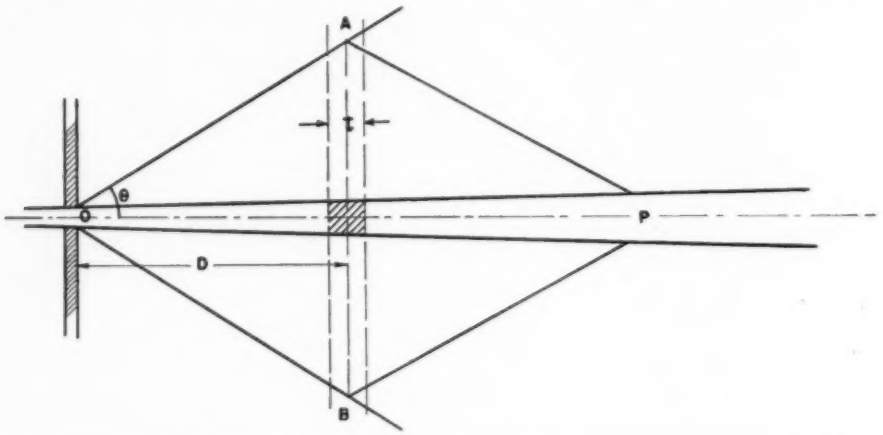

FIG. 6. Assumed conditions for estimation of ionization contributed by scattered photons.

Let E_o = the energy passing through per square centimeter of the limiting diaphragm opening at O (in a given time).

σ_a = the fraction of the energy of the gamma-ray photon which is imparted to an electron in a scattering interaction.

σ_s = the fraction of the energy of the gamma-ray photon which is imparted to the secondary photon in a scattering interaction with an electron.

N = the number of electrons in 1 c.c. of air.

E_a = the energy delivered to the secondary electrons liberated in 1 cm. thickness of air by the gamma rays passing through 1 cm.^{2} at O.

E_o = the corresponding energy delivered to the secondary photons.

Then $E_a = \sigma_a E_o N$.

$E_s = \sigma_s E_o N$.

The energy spent in producing ions within the chamber by secondary electrons originating in the primary gamma-ray beam is $E_a t = \sigma_a E_o N t$.

All secondary photons produced at point O in the beam pass through the chamber if the scattering angle is less than θ. For secondary photons produced anywhere in the beam between the diaphragm and the chamber, the limiting angle is greater than θ. Beyond the position of the chamber, only secondary photons with angles greater than 90° can reach it. The distance from which these can travel to the chamber is not limited by an obstruction (lead diaphragm) as in the case of the forward scattered photons. We shall assume, however, that those originating beyond P, at a distance D from the chamber, may be neglected. All the secondary photons which enter the chamber traverse a thickness of air greater than t. On the other hand, the conditions for the full utilization of the secondary electrons produced by the secondary photons near the periphery of the chamber are not so favorable. In view of these considerations, the value of angle θ, and the elongated shape of the scattering diagram for gamma rays, one may assume as a first approximation that nearly all secondary photons liberated in the distance D contribute to the ionization in the chamber. Obviously, most of those scattered in the forward direction pass through the chamber. Those scattered backwards do not, but are replaced by a comparable number scattered back in the portion of the beam between the chamber and P. Many of those scattered sidewise do not reach the chamber, but those that do traverse more air.

The energy, E_{sD}, delivered to the secondary photons liberated in the air thickness D by the gamma rays passing through 1 cm.^{2} at O, is

$$E_{sD} = E_s D = \sigma_s E_0 N D.$$

Since σ_a is sensibly constant in the range of wave lengths involved here, the part of this energy which we may assume to produce ionization in the chamber is the same as in the case of the primary gamma rays. Therefore the energy of the secondary photons utilized in the air volume of the chamber is

$$\sigma_a E_{sD} N t = \sigma_a \sigma_s E_0 N^2 D t.$$

The ratio of the ionization produced in the chamber by the secondary photons to that produced by the recoil electrons set free by the primary gamma rays should then be

$$\frac{\sigma_a \sigma_s E_0 N^2 D t}{\sigma_a E_0 N t} = \sigma_s N D.$$

By numerical substitution, taking $\sigma_s = 1.2 \times 10^{-25}$, $N = 3.92 \times 10^{20}$, $D = 500$, we find that this is approximately 2.4 per cent. Whether this is negligible or not is largely a matter of opinion. The actual value may be considerably lower or higher than this, since some of the assumptions made in the derivation are quite arbitrary. At any rate, it seems safe to say that the error introduced by the contribution of the secondary photons to the ionization produced in an open air chamber, under conditions which insure the complete utilization of the recoil electrons from the gamma rays of radium, is not large. If the distance between the limiting diaphragm and the center of the chamber, and also the diameter of the chamber, must be larger than assumed in the calculation ($D = 500$ cm.), the error will be correspondingly larger.

II. EXPERIMENTS WITH THE SOURCE OF RADIATION AT THE CENTER OF SPHERICAL IONIZATION CHAMBERS

A simple method by which gamma rays conceivably might be measured in roentgens, may be explained most readily in the following manner: In Figure 7, b is a narrow beam of gamma rays passing through a silk mesh chamber AB of the type already described. The ionization measured by the chamber should represent the amount of energy delivered to the recoil electrons in the shaded volume, which necessitates that AB be large. If now we curve chamber AB to form part of a spherical shell, still maintaining the radiation beam small, it may be possible to obtain the same result with a smaller chamber. Finally, if we make the ionization chamber in the form of a complete spherical shell surrounding the gamma-ray source, as indicated by the full lines S_1, S_2 in Figure 7, there is no longer any need to collimate the radiation beam. In the ordinary open air chamber setup, the air column between the diaphragm and the chamber must be sufficient to establish equilibrium between the primary gamma rays and their secondary electrons. Surrounding the gamma-ray source with the equivalent thickness of bakelite should accomplish the same result. The ioniza-

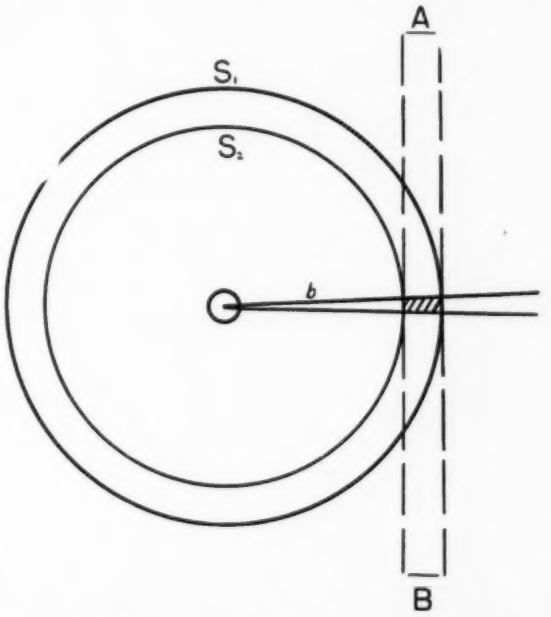

FIG. 7. Measurement of effective gamma-ray intensity by means of concentric spherical chambers with source placed at their center.

tion produced in the air space between S_1 and S_2 will be influenced by the material and wall thickness of S_1 and, to a smaller extent, of S_2. These spheres can be made of organic material of small thickness. Furthermore, neglecting wall effects, the ionization in the air between S_1 and S_2 is equal to the total ionization produced under the same conditions in sphere S_1 minus the total ionization similarly produced in sphere S_2. Accordingly, it is only necessary to measure the total ionization in two suitable spheres of different diameters. It is important to note that this procedure has the additional advantage of eliminating almost entirely the influence of the material walls of S_1 and S_2. Obviously the effective gamma-ray emission determined in this way is

$$I_e=\frac{60(I_2-I_1)}{4\pi(R_2-R_1)}.$$

Where I_1 = ionization current in e.s.u. measured with the smaller sphere of radius R_1 cm.

I_2 = ionization current in e.s.u. measured with larger sphere of radius R_2 cm.

If the conditions under which the ionization measurements are made fulfill the requirements of the definition of the roentgen, I_e would be expressed in r/min./gram (at 1 cm. distance).

By a different analysis of the problem it is possible to derive the value of I_e from the measurement of the total ionization in *one* sphere. Let

n = number of ion pairs liberated per second per c.c. of air at N.P.T. at 1 cm. from a point source of gamma rays suspended at the center of the sphere, other conditions being set by the ultimate purpose of the determination. (Under suitable conditions this is "Eve's constant".)

R = radius of the sphere in cm.

e = electronic charge in e.s.u.

$\mathcal{J}$ = saturation current in the sphere, in e.s.u.

Thus the total number N of ion pairs liberated per second in the air within the sphere (at N.P.T.) is, on the basis of the inverse square law and neglecting the attenuation of gamma rays in passing through the air,

$$N=\int_0^R\int_0^{\pi/2}\int_0^{\pi}\frac{n\rho^2\sin\theta\,d\rho\,d\theta\,d\phi}{\rho^2}$$

$$N=4\pi nR.$$

Hence $\mathcal{J}=Ne=4\pi nRe$.

From this it will be seen that the total ionization current in a sphere, with the gamma-ray source at the center, is directly proportional to the radius,—a result which is obvious from the fact that, neglecting attenuation, the gamma-ray intensity decreases as the square of the distance, whereas the volume of the sphere increases as the cube of its radius. If the conditions under which the measurements are made fulfill the requirements of the definition of the roentgen,

$$I_e=60ne$$

$$=\frac{60I}{4\pi R}\ \text{r/min./gram.}$$

The search for spheres with thin walls of organic material suitable for the purpose in question extended over a long period during which many exploratory tests were made. Rubber balloons proved unsatisfactory on account of the difficulty of making the surface conducting. Finally we learned that balloons of very thin gold beater's skin are made in England and we secured the smallest commercially available at the time, which was about 60 cm. in diameter and surprisingly close to a perfect sphere. The mass of the wall material was found to be 51 grams, from which, assuming a density of one, an average wall thickness of 0.045 mm. was deduced. This corresponds to a thickness of atmospheric air of 3.5 cm. The mass of the air enclosed in the balloon at normal atmospheric pressure and room temperature of 20°C. amounts to 142 grams and is greater than the mass of the envelope even after the lat-

ter had been coated with India ink. Accordingly this balloon fulfilled the desired condition of thin wall. Smaller spheres were made by the process employed by chemists in making collodion sacs, using spherical glass flasks. It was found that coating the collodion balloons with India ink caused considerable distortion. The difficulty was overcome by using lamp black in a dilute solution of collodion instead of ink.

The point source requirement could be met readily by using a very small glass bulb containing radon. However, since only a weak source was necessary to give the desired ionization current, the use of a small amount of radium was preferable from the point of view of constancy of gamma-ray emission. Two such sources were used for most of the experiments and radon bulbs were used in some cases. The radium sources were prepared as follows: (1) A hole 1.05 mm. in diameter was drilled in a steel ball (ball bearing) 4.75 mm. in diameter to its center and slightly beyond. A speck of radium sulphate was placed at the bottom of the hole and a steel wire about 2 cm. long was forced into the same hole as far as possible. The joint was then soldered thoroughly to prevent the escape of radon. After the radon had reached its equilibrium amount, the radium was measured by the gamma-ray method and it was found that the ball contained 0.0415 mg. of radium (element).* (2) The stronger source was made later in a different way, simply because we had a small amount of radium already enclosed in a glass rod about 2 mm. in diameter. The glass rod was cut to a length of about 8 mm., making sure that the radium was at the middle. It was then enclosed in a hollow brass sphere 12.6 mm. in external diameter, thus bringing the speck of radium to the center of the sphere. The wall thickness of the brass shell was 2 mm. The actual radiation source was very small (less than 1 mm. in diameter) and the brass filtration was the same in all directions. The disturbing influence of the glass rod could be neglected in the experiments carried out with this source. The amount of radium used in this case was 0.157 mg.

A filter of 2 mm. of brass is sufficient to remove all the primary beta rays. The steel thickness in the first source (1.85 mm.) perhaps was not quite sufficient, but additional filtration could be provided easily when necessary. The proper secondary filter to be used was determined experimentally (infra).

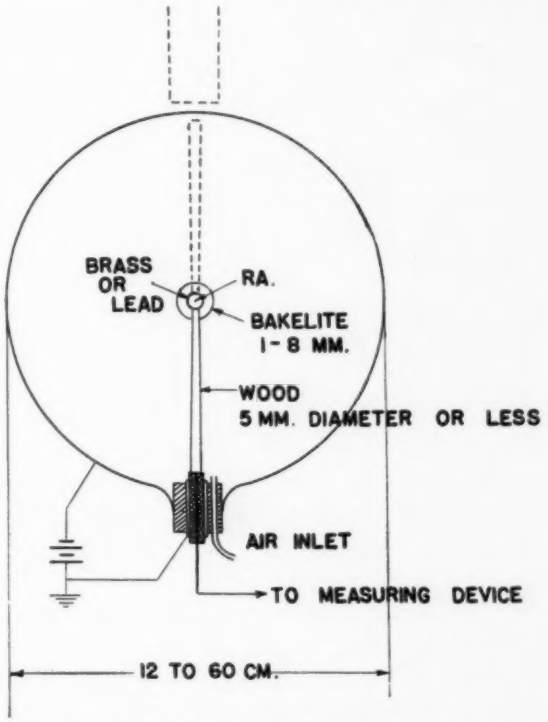

Fig. 8. Thin-walled spherical ionization chamber.

The construction of the thin-walled spherical ionization chambers, with a point source at the center, is shown in Figure 8. Since the spherical surface was not rigid, it was necessary to keep the balloons inflated at a pressure slightly higher than atmospheric pressure. A manometer was provided to determine the pressure of the air in which the ionization was measured. The necessary voltage to obtain saturation current was determined experimentally for each sphere and source. The influence of

* We take pleasure in expressing our indebtedness to the United States Radium Corporation for the preparation of this source.

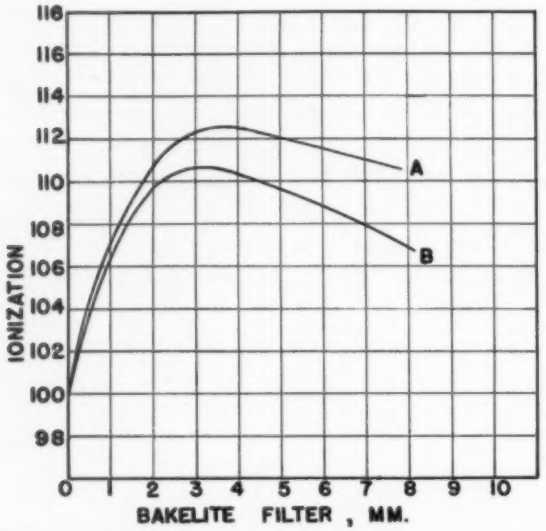

FIG. 9. Relation between ionization in spherical ionization chamber and thickness of bakelite filter around source. *A*, corrected; *B*, uncorrected.

the inner electrode and plug at the neck of the balloon was determined by adding a second electrode inside the sphere diametrically opposite to the first. It was found that the electrode correction was negligible in all cases.

To determine the proper secondary filter to use, several tests were made. In one case the steel ball source was surrounded with bakelite shells of different thicknesses, and ionization readings were taken with the source at the center of a thin copper sphere 30.5 cm. in diameter, which served as ionization chamber. (It is of interest to note in passing that the ionization produced in the copper sphere under these conditions is only about 15 per cent higher than in a collodion balloon of equal size.) The first measurement was made with the steel ball alone. This reading was taken as 100 per cent in plotting the curve of Figure 9. The relative values of the ionization produced when the ball was surrounded by different thicknesses of bakelite have been corrected for the decrease in air volume in which the ionization was measured. Since the total ionization in the spherical chamber varies directly as the radius, this correction is not negligible. No account has been taken of the decrease in gamma-ray intensity due to the bakelite. This amounts to about 0.6 per cent per millimeter. The curve shows a maximum at about 3 mm. of bakelite. Making a correction for the absorption by the bakelite, the maximum ionization would be obtained with a secondary filter of about 3.5 mm. of bakelite. In all our experiments with balloons a bakelite thickness of at least 3.65 mm. was used. It may be well to mention at this point that an increase in ionization current is obtained in a thin-walled ionization chamber placed at a distance of *4 meters* from a gamma-ray source covered with 2 mm. of brass, when a secondary filter of 4 mm. of bakelite is added. This shows that the thickness of air required to bring about equilibrium between the primary gamma radiation and its secondary electrons is greater than 4 meters (unless we attribute the increase to secondary gamma rays). (This is in contrast with the case of a collimated beam mentioned in Part I, in which the removal of secondary electrons by a magnetic field did not influence the ionization produced in an open air chamber, when the air column was about 2 meters long.)

Experiments were performed with spherical chambers of the following diameters: 12.5, 15, 28.5 and 60 cm. The dimensions given here are only approximate since upon inflation of the balloons, the diameters changed somewhat. The actual diameter and the pressure of the air were determined accurately at the time of each ionization measurement. The relation between ionization current and radius of sphere is shown in Figure 10. The smallest collodion sphere used in these experiments had a radius of 6 cm., but the curve is made to intercept the radius axis at the 0.995 cm. point, since this was the radius of the bakelite sphere around the radium. Obviously when the outer sphere is of the same diameter, there is no air space and the ionization current is zero. This point on the curve, therefore, has no less weight than those experimentally determined. Extrapolation to zero radius has no real physical meaning, since one could not ob-

tain the same radiation (both gamma and secondary beta) without the presence of considerable matter around the point source. However, the extrapolation serves to establish the zero point for the ionization current scale, when one wishes to determine the ionization current for the total volume of the sphere including that necessarily occupied by the source and but, due to physiological limitations, they did not vary much in diameter. Accordingly the first determination of the curve of Figure 10 was made (August, 1933) with the 60 cm. gold beater's skin balloon and with pig bladders having much smaller diameters (10 to 14 cm.). It was found that, taking into account experimental errors, a straight line could be drawn

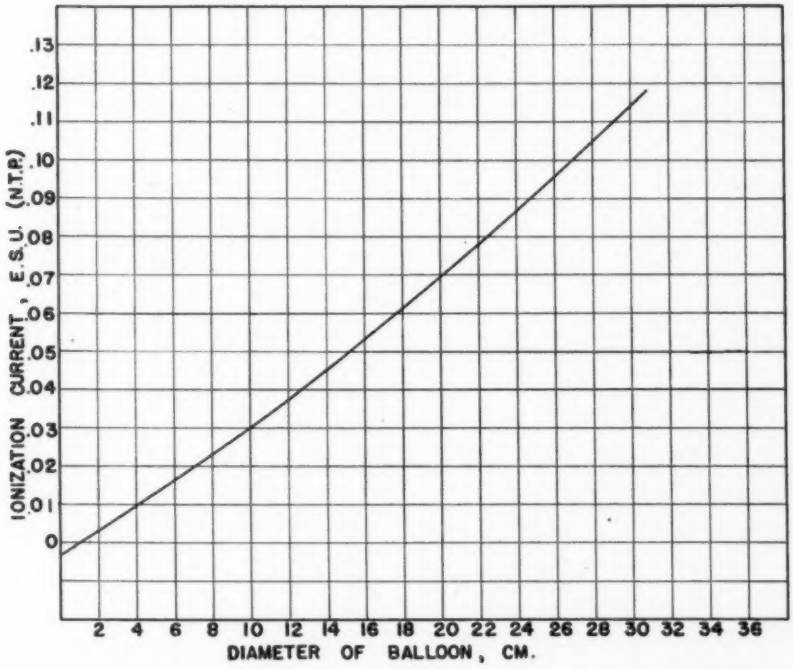

Fig. 10. Variation of ionization current in spherical chambers with radius of balloons.

filters. (The current scale in Figure 10 does not start from this theoretical zero.)

The most important result of these experiments is that the curve of Figure 10 is not a straight line. In this connection it may be well to digress a little in order to emphasize the great care which one must exercise in experiments of this sort and particularly in drawing conclusions from the results. We have already mentioned our difficulty in making very thin spheres of suitable materials. One of the attempts which proved fairly successful consisted in making balloons out of pig bladders, inflated inside of spherical glass flasks, and allowed to dry. We made several of these through the widely separated experimental points and the point of zero ionization current corresponding to the radius of the bakelite filter. Since this agreed with the "theoretical" analysis presented at the beginning of this part, we concluded that there was a straight line relation between ionization and radius of a sphere. We obtained in this way a value of 92 r/min./gram for the effective gamma-ray emission of radium. We then reasoned that if this was approximately the correct value, we should obtain it also by suspending the 60 cm. balloon chamber in free air in a very wide beam of gamma rays. We made this test in the courtyard of the hospital with

the balloon 2.86 meters above the ground and our 4 gram radium bomb at a distance of 16.7 meters. The value obtained in this manner (which involved some approximations of no significance in the present discussion) turned out to be not less than

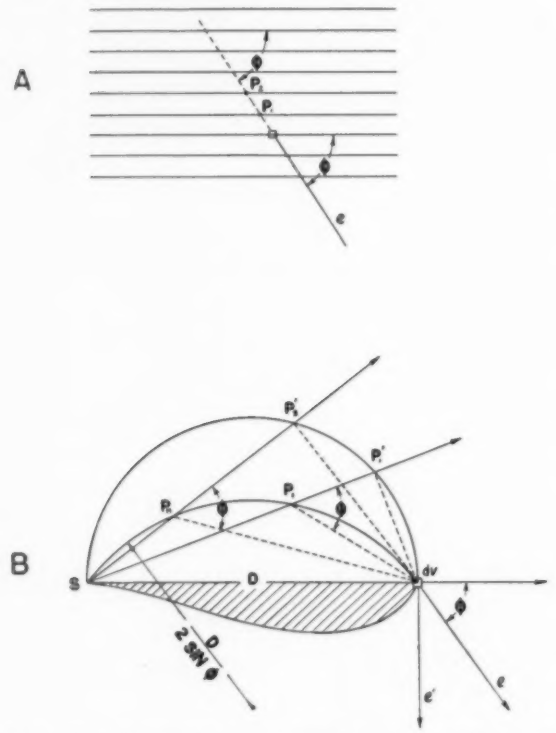

FIG. 11. Electronic compensation in parallel and divergent beams of gamma rays.

132 r/min./gram without making allowance for the absorption of gamma rays by 16.7 meters of air. This result, as well as other considerations, cast considerable doubt on the "sphere with source at center" method of measuring gamma rays in roentgens, and led to further experimentation. Of course, the non-linearity of the relation between ionization and radius of a sphere would have been found by us in any case, because the precision of the first measurements was not good enough and additional experiments with better spheres would have been made, but nevertheless we did draw the wrong conclusion temporarily.

The fact that the curve of Figure 10 is not a straight line is puzzling. One would expect that *within the bakelite filter* the gamma rays would have attained equilibrium with their secondary beta rays. Yet outside of the bakelite the ionization per cubic centimeter of air "per primary photon" increases with the distance from the source, indicating that, at least in this region, equilibrium does not exist. The increase is quite marked and can be ascertained by drawing tangents to the curve at different points. For purposes of comparison we may determine in this way the effective gamma-ray emission corresponding to the specific ionization at different distances from the source. At the surface of the bakelite sphere, 0.995 cm. radius, it is 93 r/min./gram and it increases to 135 r/min./gram at a distance of 30 cm. (These figures, being based on the tangents to the curve at the respective points, are only approximate.) Comparing these values with the one of 36 r/min./gram obtained by us with an open air chamber at a distance of 37.5 cm. from the collimating diaphragm, it is evident that electronic compensation is much better in the case of the spherical chamber determinations. Accordingly the bakelite does help considerably although it does not provide the full quota of secondary electrons to the air *at points near the source*.

A rigorous mathematical analysis of the problem is extremely difficult. Certain qualitative considerations may be of interest. In Figure 11, *A*, is represented a parallel beam of gamma rays. Assuming for the sake of simplicity that the recoil electrons travel in straight lines, for every electron e which leaves the element of volume dV at angle ϕ there are other electrons liberated in similar elements of volume at points P_1, $P_2 \ldots P_n$ at the same angle ϕ which traverse the volume dV and leave some of their energy therein. Such recoil electrons will reach the volume dV so long as point P_n is at a shorter distance from dV than the range of e_n. Hence the ionization energy left in dV by all such electrons is equal to the energy of e which manifests itself as ionization outside of dV. There is

thus complete compensation in the volume dV.

Figure 11, B, represents the case of a divergent beam of radiation with a point source at S and the element of volume dV at distance D from it. Let us assume again that recoil electrons travel in straight lines. To simplify the explanation we shall consider first the hypothetical special case of an electron liberated in dV at angle $\phi = \pi/2$. Since the gamma-ray beam is divergent, the electrons emitted at angle $\pi/2$ which are to bring about compensation, cannot be liberated along the backward prolongation of the straight line path of e, as in the case of a parallel beam. For $\phi = \pi/2$ it is obvious that points P_1', $P_2' \cdots P_n'$ lie on the arc of a circle of diameter D. Similarly for any smaller angle ϕ the points P_1, $P_2 \cdots P_n$ lie on the arc of a particular circle passing through S and dV, having a diameter equal to $D/\sin\phi$. It is evident from an inspection of the figure that points P_1, $P_2 \cdots P_n$ are all closer to the point source than dV and that therefore the number of electrons liberated at angle ϕ which might reach volume dV is larger than the number liberated at the same angle ϕ in dV. On the other hand, the divergence of the radiation beam influences also the number of electrons liberated at P at angle ϕ which actually traverse dV. Obviously the distance of P from dV is limited by the range of e for any given angle ϕ. The volume from which electrons can reach dV is that of the solid generated by rotation of the shaded part of Figure 11, B, around D as an axis. The distance D was taken equal to the range of the fastest electrons. The boundary of the shaded area was constructed by means of the range vector diagram of recoil electrons shown in Figure 12, based on the Klein and Nishina formula and the data of Varder and Schonland[16] for $\lambda = 15.1$ X.U. (825 kv.). The range in atmospheric air of the swiftest recoil electrons under these conditions is 190 cm. While the gamma rays of radium can produce recoil electrons of much longer range, this probably approximates fairly well the average conditions in a lightly filtered beam.

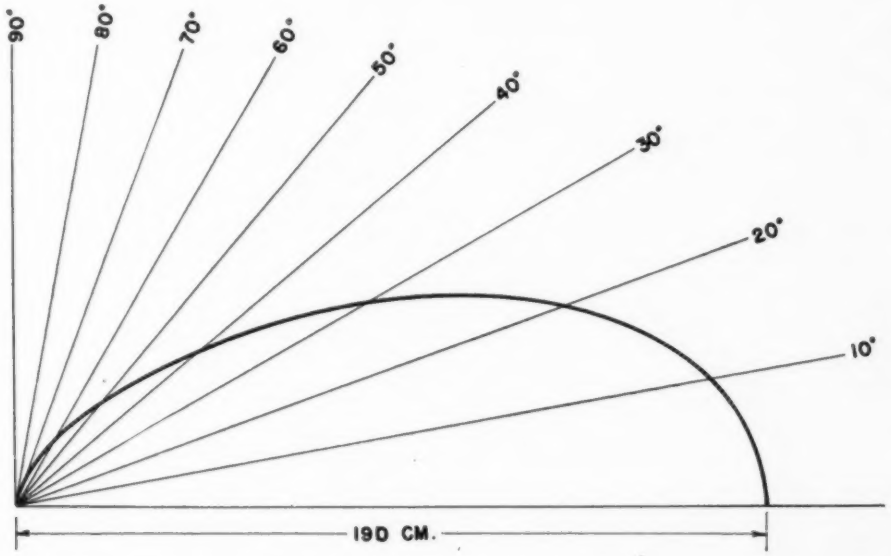

Fig. 12. Range vector diagram of recoil electrons for $\lambda = 15.1$ X.U. on the assumption that the electrons travel in straight lines.

In Figure 13 are shown the volumes of bakelite and air from which electrons may reach an element of volume dV at two different distances close to a bakelite sphere of radius equal to the maximum beta

particle range.* Remembering that the electron density of bakelite is about 1,000 times that of air, it is evident that in the case of Figure 13 practically all the recoil electrons which might reach dV are liberated in the bakelite. Since this is much closer to the source, one might suppose that the energy delivered to dV would be greater than the energy of the recoil electrons liberated in dV, in which case there would be overcompensation at this point. One can readily visualize that in the case of the electrons projected in the forward direction (traveling in straight lines) there should be exact compensation at dV. For electrons ejected at angles greater than zero, we are unable to make a definite prediction, although calculations involving simplifying assumptions indicate that there should be some overcompensation at dV under the conditions of Figure 13, as well as in the surface layer of the bakelite itself.

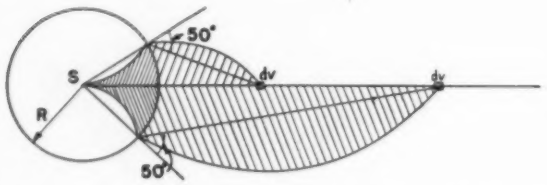

FIG. 13. Diagram showing regions from which recoil electrons, travelling in straight lines, reach an element of volume dV at two different distances from a bakelite sphere surrounding the radium source.

We may safely assume that the recoil electron conditions in a sphere of bakelite with the source at the center and within a large block of the same material, correspond to those obtaining in a sphere of atmospheric air having a diameter about 1,000 times larger. For, consider an air sphere of radius equal to the range of the fastest recoil electrons. A certain small fraction of the gamma-ray energy is transferred to a certain number of recoil electrons in this thickness of air, depending on the number of electrons in the path of the gamma rays and the laws of scattering. If the air density were doubled, the electron density in the path of the gamma rays would be doubled and the range of the recoil electrons would be halved. Thus the sphere would now have one-half the diameter of the previous one. The number of recoil electrons produced within the two spheres would be the same. Of these a certain number would traverse a thin spherical shell at the boundary of the sphere and would leave the region. The number leaving would be the same in both cases. But the area of the smaller sphere being one-quarter that of the larger one, the number of recoil electrons passing through unit area would be four times larger. Coincidentally the gamma-ray intensity at the surface of the sphere would increase in exactly the same ratio and hence the number of recoil electrons leaving the sphere *per primary gamma-ray photon*, would remain constant. Similar qualitative considerations indicate that the distribution of energy among the recoil electrons and the angular relationships of their (straight line) paths would be identical throughout the respective volumes of the spheres. Accordingly the electronic compensation at points in a surface layer of a bakelite sphere in a bakelite block should be the same as that which obtains at a distance from the source in free air equal to the range of the fastest recoil electrons. It is simpler in practice to carry out experiments in a bakelite medium.

Gray[5] has shown that when gamma rays traverse a solid material of low atomic number in which there is a small air cavity, the energy absorbed per unit mass of air or solid material in the vicinity of the air cavity is the same. Let us choose the air cavity as a thin spherical shell bounded by a bakelite sphere enclosing the gamma-ray source and a thick bakelite shell on the outside, the linear dimensions of the air cavity being small in comparison to the range of the recoil electrons. The gamma-ray intensity within the material is not uniform in this case but neither was it uniform in Gray's experimental setup for measurements close to the source. The ex-

* Neglecting recoil electrons ejected at angles greater than 50°.

periment was carried out (June, 1936) under the conditions shown in Figure 14. The result, expressed as the effective gamma-ray emission at 1 cm. distance, was 111 r/min./gram making suitable (small) corrections for the thickness of bakelite and the distribution of the source. (The ionization reading increased only slightly when

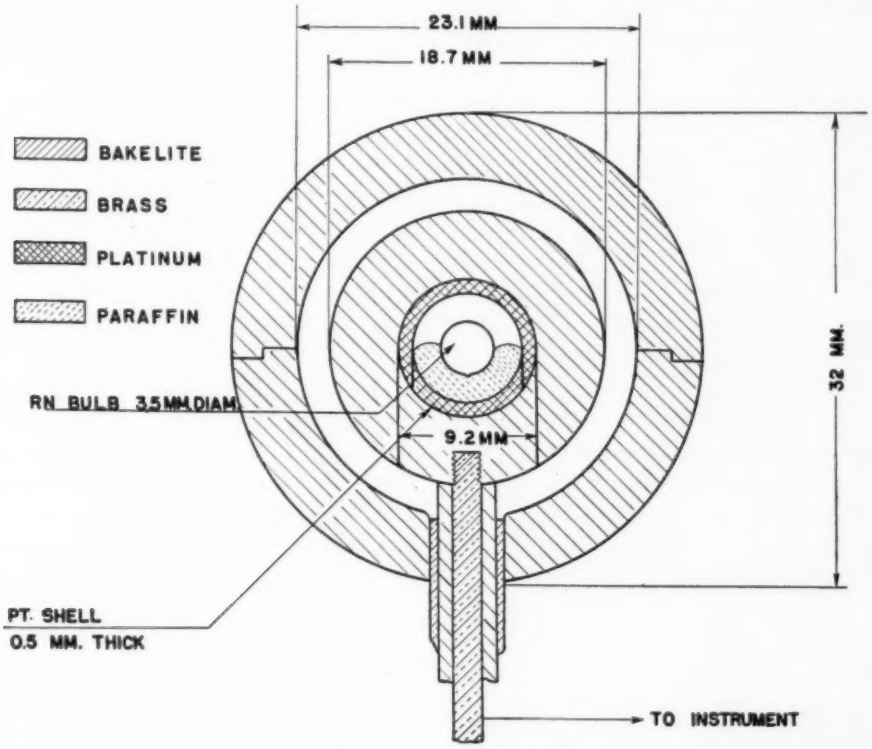

Fig. 14. Air wall ionization chamber for measurements close to a radium source.

the spherical shell chamber was "immersed" in a large rice phantom.) The value obtained by Mayneord and Roberts[12] by the thimble chamber method is 138 r/min./gram. If we assume that in the case of the thimble chamber electronic compensation is complete, it follows that in the case of the spherical shell air cavity it is far from complete. If Gray's theorem is applicable to both cases, it follows also that compensation in the surface layer of the bakelite filter must be incomplete.*

It is important to note that in an ionization chamber of the type shown in Figure 14 in which the air thickness is small, the electrons leaving the electrodes contribute considerably to the value of the current actually measured. The contribution can be determined by reversing the polarity of the saturation voltage. Thus, in the case under consideration, the current with negative potential applied to the inner sphere was 0.267 e.s.u. and upon reversing the polarity it was found to be 0.247 e.s.u. The true ionization current was therefore 0.257 e.s.u. and the *excess* number of electrons leaving the inner sphere was about 2×10^7 per second* when the radon bulb contained 54 mc. It may be pointed out, in

* An extensive investigation of the problem using spherical shell chambers of different diameters, including large ones, has been delayed by the difficulty of making suitable shells. However, we expect to carry out the experiments in the near future.

* The precision of this figure is not very high on account of the fact that it depends on the difference of two relatively large quantities involving ordinary experimental errors.

Assuming that all the ionization produced in the air shell was due to this number of electrons (2×10^7 per sec.), each produced about 25 ion pairs in passing through the air. The average path of the electrons in the air space is difficult to estimate, but assuming that it was twice the length of the air gap, namely, 4.4 mm., on the average each electron produced about 60 ion pairs per cm. This indicates that the ionization was produced largely by high speed electrons.

passing, that a similar unbalance in the electron emission from the electrodes of an ionization chamber is apt to be present in general and should be looked for. In the case of a thimble chamber it is negligible because one electrode which is very small is completely surrounded by the second one.

As we have seen, experimental evidence indicates that probably electronic undercompensation exists at the surface of the bakelite sphere even when it is surrounded by solid material. Returning to the balloon experiments, and particularly to Figure 10, we may say tentatively that the value of the effective gamma-ray emission near the bakelite sphere enclosing the source is low because compensation in the bakelite itself is incomplete. The situation cannot be remedied by increasing the thickness of bakelite. Yet at a distance of a few centimeters beyond the surface of the bakelite the effective gamma-ray emission is considerably higher. (It will be recalled that the value increased from 93 at the surface of the bakelite to roughly 135 r/min./gram at a distance of 30 cm.). Essentially the same result was obtained by using aluminum instead of bakelite as a secondary filter. Furthermore, an independent check of the increase of the effective gamma-ray emission with distance from the source was obtained by making measurements at different distances from the bakelite sphere with a small thimble chamber having very thin walls and extrapolating to zero wall thickness. Perhaps a satisfactory explanation may be found by considering the scattering of beta rays by air. Recoil electrons leave the bakelite sphere with velocities varying from zero to a maximum compatible with the wave length of the gamma rays. The scattering angles of beta particles in bakelite and air are the same, but the distances traveled between wide angle scattering encounters are in the ratio of 1 to 1,000. Accordingly, (what for want of a better term we may call) the "radius of curvature" of the path of a beta particle is very much larger in air. This refers to those particles which eventually *tend* to return to the point of origin, such as *B* in Figure 15. The recoil electrons which leave the bakelite at slow speeds "curl up" readily and lose all their energy (i.e., ionize the air) in the neighborhood of the bakelite. Those leaving at high speeds follow a course such as *A* or *B* and contribute little to the ionization near the point of origin. Owing to the great difference in density between bakelite and air, the recoil electrons which actually leave the bakelite can traverse considerable thicknesses of air. Thus the relative contribution to the ionization in the air due to the "back-scattered" electrons increases with the distance. It should be noted that, according to this view, there should be an increase in the specific ionization in air with the distance from the source, whether electronic compensation in the surface layer of bakelite is complete or not. The effect is a geometric one depending on the radial emission of radiation from a point source and the small scattering angles of fast beta particles, which preclude the possibility of a large proportion of these returning to the vicinity of the point source. This view is corroborated by the results obtained with the concentric bakelite shells ionization chamber of Figure 14. For, according to the results of the balloon experiments, the effective gamma-ray emission at the surface of the bakelite sphere is 93 r/min./gram and the addition of an exterior bakelite shell 4.4 mm. thick increases the value to 111. Additional material in the form of a large volume of rice makes little difference. Therefore, the increase must be due to electrons which are scattered back. The lack of electronic equilibrium in spite of the

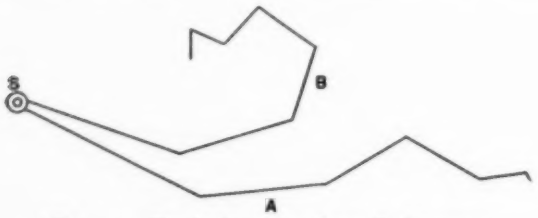

Fig. 15. Typical paths of recoil electrons.

outer bakelite shell must be ascribed again to geometric factors.

III. EXPERIMENTS WITH THE SOURCE OUTSIDE OF THIN SPHERICAL IONIZATION CHAMBERS

Since in the experiments with the source at the center of balloons of different diameters we found that the effective gamma-ray emission increased markedly with the distance from the source at which it was determined, it was important to determine its value at still greater distances. The use of larger balloons with the source at the center was not advisable on account of cost and saturation current difficulties. Accordingly measurements were made with large amounts of radon at different distances from thin balloon ionization chambers. Since the room in which the first experiments were made was not very large, long distances could not be used and the inverse square law could not be applied to the measurements with large balloons. The following formula was worked out to take into account the influence of the size of the chamber:

$$I_d = 2\pi I_1 \left[a + \frac{a^2 - d^2}{2d} \log \frac{a+d}{\pm(a-d)} \right]$$

where a = radius of spherical chamber
d = distance from (point) source to center of chamber
I_d = intensity at distance d
I_1 = intensity at unit distance
$\pm$ = Use + when source is inside sphere
Use − when source is outside sphere.

[Check measurements were made to test the validity of this formula with the source at different points inside and outside of a spherical chamber. A very close agreement could not be expected and was not found in the case of the large thin balloon on account of the increase in specific ionization with distance from the source already mentioned, and illustrated more fully by curve *A*, Figure 16.]

The results of measurements made in an ordinary laboratory room showed that the effective gamma-ray emission continued to increase quite rapidly with distance. We could attribute the increase, at least in part, to radiation scattered by the room walls. Thus it became necessary to find a large room in which the experiments could be carried out under better conditions. The room we were able to use finally was 6.7 meters wide, 16.5 meters long and about 9 meters high. Thin collodion or gold beater's skin chambers of the same sizes used previously were also used in this case. Each chamber was mounted with the center 2.7 meters from the floor, 3.35 meters from either side wall and 3.00 meters from the "back" wall. The gamma-ray source was placed at the same height from the floor and moved to different distances from the chamber along the long axis of the room. For the longest distance used, 9 meters, it was still 4.5 meters from the nearer end wall. To increase the precision of the measurements, the size of the chamber was increased with the distance, and overlapping readings were taken with two different chambers. The results shown by curve *A* in Figure 16 were obtained (February, 1934) for distances greater than 1 meter, with the source enclosed in a brass filter 2 mm. thick, surrounded by 4 mm. of bakelite and suspended by a thin thread at the proper distance from the chamber. The portion of the curve for distances shorter than 1 meter was obtained with smaller ionization chambers having also very thin walls of organic material. The value at 1 cm. distance, 93, is the one obtained with the source at the center of the balloons by extrapolating to the surface of the bakelite sphere. The values obtained by the same experiments between 1 and 30 cm. fit the curve very well. All distances were measured from the center of the source to the center of the ionization chamber. The ordinates represent the ionization per cubic centimeter of air per gram of radium reduced to 1 cm. distance by the inverse square law. There is no justification for ex-

pressing this in r/min./gram, but we have done so in order to emphasize the great difference in the value of the effective gamma-ray emission obtained by simply varying the distance at which the measurement is made with a thin-walled chamber. A small correction was made for the absorption of gamma rays by the bakelite secondary filter. No allowance was made for the absorption of gamma rays by the intervening air, which would increase somewhat the slope of the latter part of the curve.

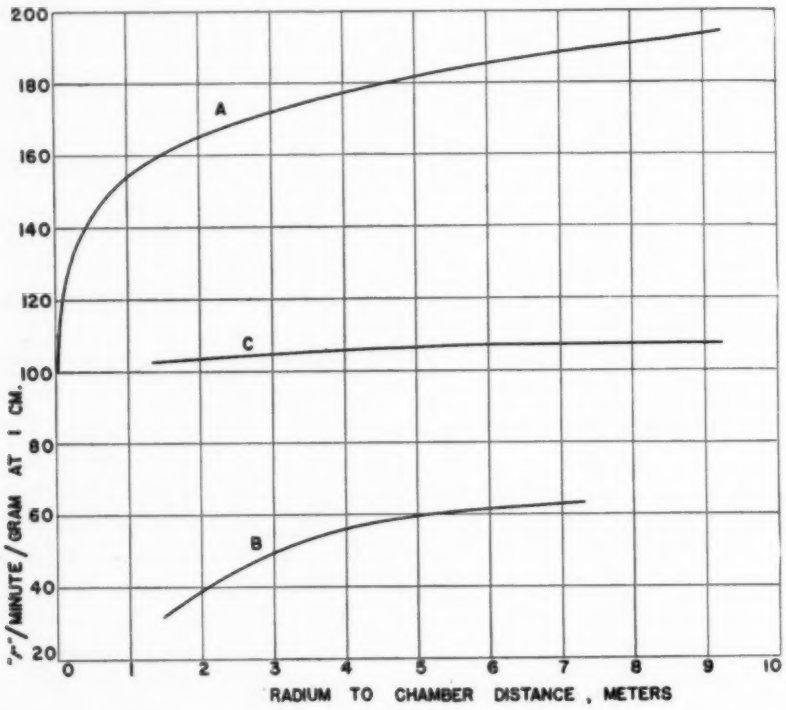

FIG. 16. Measurements with thin-walled ionization chambers. *A*, chambers and source in free air; *B*, chambers in collimated radiation beam; *C*, chambers in shadow beam.

The most striking thing is that the effective gamma-ray emission apparently increases from 93 to over 190 r/min./gram as the distance at which the measurement is made varies from 1 to 900 cm. If the bakelite around the source was capable of bringing about equilibrium between the gamma radiation and its secondary electrons, what is responsible for this large increase? To account for the increase between 1 and 30 cm. found in the experiments with the source at the center of the chamber, we pointed out in a previous section that the geometric conditions imposed by the point source and the small angle scattering of fast beta particles call for an increase in the specific ionization with distance, irrespective of what the bakelite may do. Mention was also made of the fact that the addition of the bakelite to the brass filter *increases* slightly, but nevertheless definitely, the ionization current in a thin chamber even at a distance of 4 meters. It might be supposed that this increase is due to gamma rays scattered by the bakelite. Kaye and Binks,[9] however, in more recent experiments of the same type, show that the influence of a magnetic field at the gamma-ray source is felt by a thin-walled chamber at a distance of 5 or 6 meters. This can only be due to electrons. It is evident, therefore, that at least part of the increase in the specific ionization up to

a distance of 6 meters must be attributed to "a better utilization" of recoil electrons, some of which originating in the bakelite still reach the chamber at this distance.

The rise of curve *A* beyond the 6 meter distance must be ascribed almost entirely to secondary gamma rays, which means that part of the rise at shorter distances was also due to the same cause. It becomes necessary, therefore, to consider the influence of scattered photons on ionization readings obtained with thin chambers at relatively short distances from the source. In the course of the experiments with the source at the center of the chamber, tests for the part which might be attributed to scattered gamma rays were made by placing lead plates very close to the large balloon chamber and by suspending the latter very close to the concrete floor of the room. The increase in the ionization reading was negligible. Experiments carried out with a papier maché spherical chamber (17.1 cm. diameter, 2 mm. wall thickness) at distances of 0.5 to 3.5 meters from the source in two rooms of very different size show practically no difference in results. Similar experiments with thin collodion chambers give a slightly higher ionization current in the case of the smaller room and the longer distances, but the difference is within the limits of experimental error. It is undoubtedly safe to conclude that for radium to chamber distances smaller than 1 meter, the ionization current is not influenced appreciably by scattered gamma rays originating in the walls, floor and ceiling of an ordinary laboratory room. Nevertheless, according to curve *A* of Figure 10, the effective gamma-ray emission determined with thin-walled chambers at 1 meter distance, 153 r/min./gram is considerably higher than the value of 138 obtained with thick-walled thimble chambers. It is of interest to mention in this connection that measurements made with a spherical celluloid chamber, 8.1 cm. in diameter and 1 mm. wall thickness, give a constant value for the effective gamma-ray emission for source to chamber distances between 12.68 and 126.8 cm. The higher readings obtained with thin-walled chambers must be due to secondary electrons which cannot penetrate 1 mm. of celluloid. The thick wall of a thimble chamber, recommended for the measurement of gamma rays, is supposed to provide in the air volume the proper electronic balance. If this is so then there must be electronic overcompensation in the air at moderate distances (50 to 100 cm.) from a point source of gamma rays surrounded by a bakelite filter, whereas at distances shorter than 30 cm. there is undercompensation. Why this should be so it is difficult to see, although one may account for the effect in a qualitative way by assuming that some of the fast beta particles originating largely in the bakelite are scattered backwards after they have traversed a certain thickness of air. The question now arises as to whether the presence of these back-scattered electrons is or is not necessary to bring about equilibrium between the gamma radiation and its secondary electrons. Whatever the correct answer to this question may be, it is evident that in the case of a point source surrounded by a certain thickness of bakelite, the specific ionization in air varies with distance according to curve *A* of Figure 16,* and that one cannot alter the situation by choosing a particular criterion of equilibrium. Thus, whether in the air of the small thick-walled thimble chamber there is just complete electronic compensation or not, measurements by this chamber would give an erroneous value of the ionization actually taking place in free air at different distances from a point source of gamma rays.

The shape of curve *A* beyond the 1 or 2 meter distance is influenced undoubtedly by gamma radiation scattered by the room walls and floor. (The ceiling was too high to contribute much.) Radiation scattered by the air must also play some part. That a considerable proportion of the ionization at long distances is due to scattered gam-

* Neglecting for the moment the possible influence of radiation scattered by the room walls.

ma rays is demonstrated by the following experiments. Two complementary lead cones 22.5 cm. long were used. That is, a hollow lead cone with the source at the apex was used to provide a collimated beam of gamma rays. The second lead cone was solid and fitted into the hollow one. With the source suspended at its apex this cone provided a "shadow beam" of the same size as the collimated radiation beam. Ionization readings were taken in the two "beams" with thin spherical chambers at different distances from the source (March, 1934). For each chamber diameter a distance was chosen such that the cross-section of the beam was somewhat larger than the balloon. The results are shown by curves *B* and *C*, Figure 16, reduced to r/min./gram at 1 cm. distance, simply for purposes of comparison. It is interesting to note that the values obtained in the "shadow beam"are higher and practically constant throughout a long range of distances. This means that the contribution of scattered electrons (and gamma rays) originating in the air outside of the shadow beam (and the room walls) is large and substantially constant beyond a 2 meter distance. On the other hand, in the case of the radiation beam, the values increase steadily, because at first a considerable proportion of the recoil electrons are scattered out of the beam and some of these return into it at a greater distance. Also, as the beam gets larger fewer electrons are scattered clear out of the beam. (Adding the ordinates of curves *B* and *C* should give curve *A*. That this is not the case is due to the fact that the ionization chambers were somewhat smaller than the cross-sections of the radiation and shadow beams at the distances where readings were taken.)

In order to get some idea of the nature of the radiation responsible for the ionization within the shadow beam, readings were taken with the papier maché chamber already mentioned, with two copper spherical chambers (0.7 mm. wall thickness and 20 and 30 cm. diameters respectively), and with a lead chamber (1.57 wall thickness and 30 cm. diameter), each chamber being placed at the distance from the source where the cross-section of the shadow beam was somewhat larger than the sphere (4.5 meters in the case of the 30 cm. chambers). In all cases the ionization values obtained, reduced to the 1 cm. distance, were between one-third and one-half of the values obtained with the thin spherical chambers. This indicates that a considerable portion of the ionization within the shadow beam is produced by scattered gamma rays. A proper appraisal of this contribution cannot be made because of the different absorption and ionization functions of the metal chambers for radiation of unknown wave length. The papier maché chamber was probably too thin to discriminate correctly between beta and gamma rays. The measurements with copper chambers at two distances show that the influence of scattered gamma rays increases with the distance. The copper thickness, 0.7 mm., may also have been too small for complete absorption of all recoil electrons. The experiments just described are obviously incomplete. On account of the uncertainty as to what proportion of the scattered gamma radiation originated in the room walls, we had intended to repeat the experiments in a still larger room, or perhaps in the open air, and at that time make a more extended study of the beta and gamma ray components reaching the shadow beam. However, this is another case where the results and conclusions to be drawn therefrom did not justify the effort, and the problem was abandoned.

V* CORRELATION OF IONIZATION MEASUREMENTS AND BIOLOGICAL EFFECT

We shall assume that gamma rays can be measured *in roentgens* by means of a thimble chamber of suitable material, with the proper wall thickness, as recommended, for instance, by Mayneord. We

* Part IV of this paper, describing experiments with thimble chambers, will appear in a later number of this JOURNAL.

find thus that the effective gamma-ray emission of radium is 138 r/min./gram (8.3 r/mg-hr.) at a distance of 1 cm. from a point source properly filtered. If this constant, or the method by which it is derived, is to be of practical value, it should permit us to express gamma-ray doses in roentgens in the treatment of patients or in biological experiments, either by calculation or by actual measurement with the accepted thimble chamber. Let us see what happens in a few cases in which reasonably accurate data are available.

Henshaw and Francis[7] have determined the mortality of *Drosophila* eggs exposed to gamma rays at the surface of a bakelite sphere 9.3 mm. in radius, with the source at the center. (The original article should be consulted for details of the experimental conditions.) The thickness of the bakelite was 4.7 mm., which does not differ greatly from the thickness recommended for the thimble chamber. They found that 50 per cent of the eggs were killed by an exposure of 1,900 millicurie-minutes. How many roentgens does this represent? If the effective intensity is 138 r/min./gram at 1 cm., at the shorter distance of 0.94 cm. corresponding to the position of the eggs, it is $138 \times 1/(0.94)^2 \times 0.97 = 152$ r/min./gram, allowing 3 per cent for the absorption of gamma rays by the bakelite. Therefore 1,900 mc-min. are equivalent to $1.9 \times 152 = 289$ r. The same authors report that in a parallel series of experiments in which the biological conditions were kept as nearly constant as practicable, the 50 per cent killing dose for *Drosophila* eggs exposed to filtered 200 kv. roentgen rays was found to be 197 r. The difference between 197 and 289 is much larger than any reasonable experimental error. Therefore, we must conclude that it takes considerably more *roentgens* of gamma radiation than of roentgen rays to kill *Drosophila* eggs.

It will be contended, of course, that when the eggs are on the surface of the bakelite sphere suspended in free air, the electronic conditions are not such as are required by the definition of the roentgen. Surrounding the sphere with a bakelite shell 3.5 mm. thick should remove this objection. Exner and Packard[13] have performed this very experiment under carefully controlled conditions. They exposed *Drosophila* eggs on the surface of the bakelite sphere, with and without a bakelite shell, of such diameter that the air space was only 1.66 mm. The difference between the two sets of results is too small to be significant. The results obtained without the bakelite shell are in good agreement with those of Henshaw and Francis. It is safe to conclude, therefore, that the addition of the bakelite shell does not alter the biological effect materially.

Now let us make the ionization measurements under conditions which, as far as one can judge, are identical with those obtaining at the surface of the bakelite sphere, where the eggs were placed for irradiation. It will be recalled that, in the experiments with the source at the centers of thin balloons, described in Part II, a slight increase in thickness of the bakelite used as a secondary filter beyond the first few millimeters had practically no effect on the ionization produced within the spherical chamber (see Fig. 9). Accordingly, the addition to the bakelite sphere of the thin wet paper strips carrying the eggs had the effect of increasing slightly the diameter of the sphere, but caused no appreciable disturbance otherwise. The ionization produced in the air immediately surrounding the bakelite represents closely the ionization which is effective in producing the biological change. We have shown in Part II that the ionization at the surface of a bakelite sphere of 1 cm. radius is 93 "r"/min./gram. The quotation marks are used to emphasize the fact that this is not the same r as measured with a thimble chamber. Reducing the value to 0.94 mm. distance at which the eggs were placed, and correcting for the thickness of bakelite, we find that the effective gamma-ray intensity at the position of the eggs is $93 \times 1/(0.94)^2 \times 0.97 = 102$ "r"/min./gram. Therefore the

dose of gamma rays required to kill 50 per cent of the eggs on the surface of the bakelite sphere suspended in free air is $102 \times 1.9 = 194$ "r." This agrees very well with the value of 197 r which applies to hard roentgen rays. It follows, therefore, that when the ionization measurements are made under the physical conditions which obtain in the biological material during the irradiation, the discrepancy between the effectiveness of roentgen rays and gamma rays disappears, at least in this case.

We do not wish to imply by the close agreement in the two figures given above that the accuracy of either the physical or the biological determinations is as high as indicated (assuming that there is no biological difference due to wave length). In work of this character better agreement than within ± 5 per cent can hardly be expected. This is illustrated by Exner and Packard's[1] inability to find a definite difference in the results obtained with and without the addition of a bakelite shell, although our measurements under the two conditions (Part II) indicate a difference in the ionization at the surface of the sphere of about 20 per cent. The important point is that the value of the effective gamma-ray emission (138 r/min./gram) determined with the thimble chamber, is of no use whatever when one wishes to determine the *ionization dose* which is responsible for the lethal action of gamma rays on *Drosophila* eggs exposed on the surface of the sphere. That the actual ionization dose is the all important quantity which the biologist or radiologist must know can hardly be contested. In the case just discussed, the desired information could be obtained only by experiments such as ours or by others equivalent thereto.

We shall now discuss a second case. Henshaw and Francis[7] exposed *Drosophila* eggs on the surface of a hard rubber cylinder of 1.115 cm. radius, containing at the center radon in a few capillary tubes 1.5 cm. long, filtered by 2 mm. of lead. (The original article should be consulted for other details.) They found that 50 per cent of the eggs were killed by an exposure of 3,100 mc-min. In order to determine the average effective intensity of radiation to which the eggs were subjected, it is necessary in this case to make allowances for (1) the distributed source, (2) the lead and hard rubber filtration (which is different for different parts of the source) and (3) the breadth of the cylindrical area on which the eggs were placed (about 1.2 cm.). Paterson and Parker[14] have published dosage charts based on a value of 8.4 r per mg-hr., which is practically the same as the one (8.3) adopted for the purpose of the present discussion. Chart 4 of Paterson and Parker is for tubes with a filter of 1.5 mm. of platinum, which as a first approximation may be taken to be equivalent to the 2 mm. of lead and 8 mm. of hard rubber in the cylinder in question. From this chart, by suitable interpolation and conversion, one obtains the intensity at the midline of the egg-covered area. It is 76 r/min./gram.* It is hardly necessary to calculate the average intensity over the area occupied by the eggs. It is certainly not higher than 70 r/min./gram. On this basis the dose required to kill 50 per cent of the eggs is approximately $3.1 \times 70 = 217$ r. We now have the peculiar result that the 50 per cent killing dose of *gamma rays* expressed in roentgens is quite different for eggs irradiated on the surface of a bakelite sphere and a hard rubber cylinder of about the same radius. The difference (289 for the sphere and 217 for the cylinder) is quite large, and cannot be attributed to experimental errors.

To determine the ionization dose in this case we constructed cylindrical ionization chambers of hard rubber, with the source and filter identical with those of the cylinder used in the fly egg experiments. The collecting electrode was of the same size as the area over which the eggs were distributed. Cylinders of three different diameters were used, in the range of 1 cm. radius. The outer electrode consisted of a coaxial cylinder of inked silk net, which

* By a graphical method we have estimated the intensity to be 81 r/min./gram. Either one serves the purpose equally well.

could be replaced by cylinders of the same diameter but of different thicknesses of paper or celluloid. This permitted us to extrapolate to zero wall thickness. The spacing between electrodes was varied for each chamber from about 0.5 mm. to 3 or 4 mm. by using outer cylinders of different diameters. This enabled us to extrapolate to zero air thickness, in order to determine the ionization at the surface of the inner cylinder. The average intensity thus obtained for the conditions which apply to the *Drosophila* egg experiments was 65 "r"/min./gram. Hence the 50 per cent killing dose is $3.1 \times 65 = 202$ "r," which agrees well with the value for the sphere, 194 "r," and the value for hard roentgen rays, 197 r. The fact that this agrees also with the calculated value based on thimble chamber measurements, 217 r, is a mere coincidence. For, if this is correct, how can we reconcile it with the value of 289 r obtained by much simpler calculation in the case of the sphere?

It may be well to mention that the physical measurements and the biological determinations were carried out entirely independently. Exner and Packard, and Henshaw and Francis did not know the results of the spherical chamber experiments at the time they performed the experiments with *Drosophila* eggs on the bakelite sphere, although the work was undertaken at our suggestion. Packard[13] published the results of experiments with the hard rubber cylinder in 1928. It was with the idea of determining the *ionization dose* of gamma rays required to kill 50 per cent of the eggs under these conditions that we made the measurements with the appropriate "extrapolation chambers" in May, 1934. Based on the exposure of 5,300 mc-min. reported by Packard, we obtained an ionization dose of 345 "r." This was almost double the equilethal roentgen-ray dose of 180 r reported by Packard in the same paper. The discrepancy puzzled us for a long time, but it disappeared after Henshaw and Francis[7] found that the 50 per cent killing exposure with the same cylinder as used by Packard was 3,100 and not 5,300 mc-min.

We shall consider now some cases which have a more direct bearing on dosage in radium therapy. MacComb and Quimby[10] have determined the threshold erythema dose with a hard rubber cylinder like the one used in the *Drosophila* egg experiments, except that the diameter was 10.75 instead of 11.15 mm. The applicator was strapped to the forearm of patients, and the dose required to produce a threshold erythema was determined by the method which has been used extensively at the Memorial Hospital for many years.[15] The threshold erythema dose under these conditions was found to be 225 mc-hr. Again making use of Paterson and Parker's Chart 4, we find that the intensity at the surface of the cylinder is 83 r/min./gram.* From what has appeared in the literature thus far, we would assume that in this case back-scattering is negligible, since it is known that back-scattering in the case of gamma rays is small, the source was close to the skin, and the mass of tissue irradiated was small. An allowance of 5 per cent is therefore liberal. The intensity at the surface of the skin may be assumed to be 87 r/min./gram, and the threshold dose is then 1,170 r.

The determination of the ionization dose in this case involves some approximations, since we have not determined it under the exact conditions obtaining at the surface of the skin, namely, with a scattering mass touching the cylinder on one side only. The value without the scattering material is 72 "r"/min./gram at the surface of the cylinder. Adding 5 per cent for back-scattering, as before, we obtain 1,010 "r" for the threshold erythema dose.

The threshold erythema dose has also been determined in the same way at the Memorial Hospital for the 4 gram radium pack. A sheet of celluloid 3 mm. thick was used between the mouth of the pack (10 cm. in diameter) and the patient's arm. With both the pack and the arm in contact with the celluloid, the radium-skin distance

* The value obtained by our graphical method is 87.

was 6.3 cm. While the filter in this applicator is more than 0.5 mm. of platinum, the exact value is difficult to obtain, since the radium capsules are placed on end, and a large proportion of the radiation must traverse not only considerable radium salt but also considerable platinum obliquely through the side walls of the capsules. It is preferable, therefore, to measure the effective intensity of radiation at the 6.3 cm. distance rather than derive it from charts. Using a small (thick walled) spherical chamber of celluloid, it was found that the intensity was 11.2 r/min. The back-scattering measured with the same chamber and a large water phantom amounted to 11 per cent. In the case of the arm it can hardly be more than 5 per cent. The threshold erythema is produced by an exposure of 127 minutes, or a dose of 1,490 r.

To determine the ionization dose at the surface of the skin under the conditions of treatment, a special "extrapolation" chamber was used. The upper electrode was a sheet of celluloid 3 mm. thick, as used in the skin tests. The lower electrode, also of celluloid, was backed by 15 cm. of rice and flour to provide the scattering material. The volume of this material was much larger than the forearm. The distance between the parallel electrodes could be varied by micrometer screws, so as to permit extrapolation to zero air thickness. The beam of radiation traversed the chamber normally to the plates. The collecting electrode consisted of an inked circle 3 cm. in diameter at the center of the lower plate with appropriate guard ring.*

Measurements with this chamber at the 6.3 cm. distance from the radium in the pack indicate that the average intensity over the 3 cm. circle at the center of the beam, is 9 "r"/min. It is important to note that this is the value of the ionization per cubic centimeter of air in a very small thickness of air between two celluloid sheets of which the upper one traversed by the radiation is 3 mm. thick, and the lower one 3 mm. thick is backed by a block of rice and flour 30 cm. in diameter and 15 cm. thick. The reading therefore includes practically all the back-scattering that might be expected under these conditions. In spite of this it is much lower than the value of 11.2 r/min. obtained with a thimble chamber placed at the same point in the beam, *without the scattering material*. The reading at the surface of a water phantom, with the thimble chamber half submerged was found to be 12.3 r/min. Accordingly this is the value which should be compared with that of 9 "r"/min. obtained with the extrapolation chamber. It is very difficult to account for the marked difference between the two. The problem is being studied further. It might be mentioned at this time that, in the case of filtered 200 kv. roentgen rays, measurements with the two types of ionization chamber agree very closely.

Since the value of 9 "r"/min. obtained with the extrapolation chamber includes more back-scattering than was present in the skin of the arm, we shall deduct 5 per cent from the reading. Thus the threshold erythema dose in terms of the ionization in air, under conditions comparable to those existing in the skin of the arm, is $9 \times 0.95 \times 127 = 1{,}090$ "r." This agrees quite well with the corresponding ionization dose 1,010 "r" obtained in the case of the hard rubber cylinder. On the other hand, the doses in terms of the roentgen as measured by the thimble chamber and applied to the two cases do not agree so well. They are 1,170 r for the cylindrical applicator and 1,490 r for the pack. This indicates that the "ionization dose" determined under the physical conditions obtaining in the irradiated tissue by the extrapolation method is a better index of the biological effect which may be expected than the dose in roentgens based on measurements with the accepted thimble chamber.

As a matter of general interest, we may add at this point that the threshold erythema dose determined by the extrapola-

* The design of extrapolation chambers for different purposes is discussed by Failla in the August, 1937, number of *Radiology*. For this reason details are omitted at this time.

tion method is approximately 630 "r" in the case of 200 kv. roentgen rays filtered by 0.5 mm. of copper. (Both the gamma-ray and roentgen-ray threshold erythema ionization doses are subject to slight modifications, since we have been unable so far to make the extrapolation chamber measurements with a scattering mass of the same bulk and shape as the average human forearm.) It might be mentioned also that the threshold erythema ionization dose for 85 kv. roentgen rays filtered by 1 mm. of aluminum is about 225 "r." If the method of measurement is correct, it is evident that the number of ions required to produce the threshold erythema on human skin becomes larger as the wave length of the radiation becomes shorter. In the region of ordinary roentgen rays up to 200 kv., the change is more rapid than in the supervoltage and gamma-ray regions. On the other hand, the same ionization dose of roentgen rays and gamma rays has the same lethal action on *Drosophila* eggs.

The results just discussed are summarized in Table 1.

Table I

Test Object	Gamma Rays		Roentgen Rays
	Roentgen dose, r	Ionization dose, "r"	
Drosophila eggs on sphere	289	194	197
Drosophila eggs on cylinder	217	202	
Human skin (cylinder)	1,170	1,010	For half-value layer 1.0 mm. Cu 650
Human skin (pack)	1,490	1,090	For half-value layer 1.7 mm. Al 225

It is evident at a glance that gamma-ray doses required to produce the same biological effect under different, but nevertheless comparable, conditions are in closer agreement when they are expressed in terms of the ionization in air produced under the physical conditions obtaining in the test object during irradiation.

CONCLUDING DISCUSSION

We are of the opinion that adoption of the thimble chamber method for the measurement of gamma rays in *roentgens* is premature. There is no urgent need for this at present as will be seen from the following considerations: Certainly there is no need for the use of a thimble chamber to check the radiation output of the elementary radium sources (tubes, needles, etc.) as in the case of roentgen tubes. Since in radium therapy short source to tissue distances prevail, measurements of radiation intensity and its distribution must be made with very small chambers, requiring very sensitive instruments and the method is not a practical one for use in the clinic. This applies with more force to the measurement of "tissue dose" which is the most important factor the radiologist should know. Dosage charts, such as those of Paterson and Parker, would not become more useful by the adoption of a fixed value for the effective gamma-ray emission of radium. In fact, these charts are based on the constant 8.4 r/mg-hr. at 1 cm. distance from a point source, but the advantage gained thereby is only illusory. The reason for this is that the numerical value of this con-

stant (8.4 or any other) influences only the dosage scale of the charts, but does not change the relative shapes and positions of the curves. This is a very important point and deserves further elucidation.

By the use of Paterson and Parker's charts we can determine, for instance, the dose in roentgens administered to the skin of a patient in a given treatment. Assuming that all other physical conditions are the same, can we expect the biological changes produced in the skin to be the same as would be produced by an equal dose of ordinary roentgen rays expressed in roentgens? At least some radiologists would answer this question in the negative and would give as a reason the difference in the biological response of the skin to the two qualities of radiation. This is not the point we wish to bring out. We may well expect a difference in skin reaction because in general the *ionization dose* and the roentgen dose do not bear the same relation to each other when the quality of the radiation varies within wide limits. This has nothing to do with the biological wave length dependence. What complicates the problem still more is that the ionization dose and roentgen dose do not bear the same relation to each other within the gamma-ray region itself. The ratio of the two depends on factors which are but little understood today. If the ratio remained constant it would be a simple matter to apply a correction factor, which would be equivalent to assigning a different but still constant value to the milligram-hour r equivalent.

In some of the illustrative cases considered in the correlation of dose and effect, we included the back-scattered radiation in the dose expressed in roentgens. The propriety of this procedure is questionable, since, strictly speaking, the roentgen applies to a beam of radiation in which the scattered component does not contribute appreciably to the ionization of the air in the chamber. Accordingly the roentgen should not be used as a unit of tissue dose. As a matter of fact, whether implicitly or explicitly, it is being used for this purpose by most radiologists, because tissue dose is the factor which they need most in their work. Why not then adopt a unit which is best suited for this purpose? The definition of such a unit might be as follows: The roentgen is the quantity of any ionizing radiation capable of producing 1.615×10^{12} ion pairs per gram of air at a given point in a given medium under the conditions in which the radiation is to be utilized. By this definition the magnitude of the roentgen in the ordinary roentgen-ray range would remain the same as it is at present. There would be no practical complications. The unit could be used for measurements of radiation in air or tissues.

We realize, of course, that this would necessitate a great deal of experimental work to determine the ionization doses in the irradiated tissues under all the conditions of treatment used in radium therapy. It should be noted, however, that this must be done no matter what unit may be adopted, since otherwise the correlation of dose and effect cannot be made properly.

The suggested unit is applicable to any type of radiation and high speed particles which directly or indirectly ionize air. As the use of neutrons and artificial radioactive substances in biology and therapy increases, the demand for a suitable unit of dosage will become acute. In fact, already, in the absence of such a unit, the roentgen has been drafted to serve a purpose for which it was never intended—the specification of neutron doses. In other words, whether one likes it or not, the general conception of the roentgen is that it represents a certain number of ions per cubic centimeter of air, no matter how produced. We feel that the situation could be clarified by changing the definition of the roentgen.

The only valid reason for the desire to extend as soon as possible the use of the present roentgen to the gamma-ray region is to be found in the rapidly increasing number of supervoltage roentgen-ray generators in actual use. A satisfactory method of calibrating these machines should be

adopted. It is being done at present largely by means of thimble chambers. The practice may well be continued until the question of the definition of the roentgen is definitely settled.

So far as we know, the measurement of "ionization doses" under the actual physical conditions of treatment, in the gamma-ray region, has been undertaken only in our laboratory. We have worked on the problem during the last three years and therefore we have had time for mature consideration. The "extrapolation" method is the only one we have found so far which is capable of providing the information essential to the proper correlation of radiation dose and effect. It is very important that similar work be carried out in other laboratories to substantiate or disprove our findings. In the meantime let us keep an open mind.

We take pleasure in acknowledging our indebtedness to the former and present members of the laboratory staff, whose whole-hearted cooperation was very valuable in the course of the work: John E. Rose, Stephen Suozzi, and John Wolke, as well as Edith H. Quimby.

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RADIOTHERAPY FOR ENDOTHELIOMA OF BONE*

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IT IS astonishing how long it takes for knowledge to permeate the rank and file of any profession. When an important discovery is made, the discovery itself and its outstanding applications, especially if these be startling enough to attract the attention of newspaper and magazine editors, may become known fairly rapidly but, in the case of more prosaic discoveries in limited fields of science, a generation may be required before a relatively simple fact becomes known to the average member of a profession. And the medical profession is not an exception.

It is now fifteen years since Ewing pointed out a variety of bone tumor which he regarded as distinct from other tumors affecting the bony skeleton because it possesses certain characteristics that distinguish it from all other varieties. These distinctive features are four in number: (1) a tendency to absorb or to destroy bone and never to produce bone; (2) slow metastasis; (3) a tendency to invade soft parts, and (4) a marked susceptibility to roentgen rays and radium. Ewing recognized three forms of endothelioma, and he described them so well that his descriptions as well as the features that characterize the entire group should be memorized by every physician who cares to be well informed about tumors of bone.

A point which cannot be emphasized too much is that this variety of neoplasm constitutes a more important proportion of bone tumors than most physicians seem to realize. As the recognition of endothelioma of bone increases, it may prove to be actually more common than true osteogenic sarcoma or chondrosarcoma.

Unfortunately, through lack of special study or for other reasons, many pathologists are still unable to recognize or unwilling to admit the identity of endothelioma of bone as such. Moreover, certain pathologists still question some of the features of endothelioma pointed out by Ewing. Many such tumors are still being labelled as round cell, or even as osteogenic, sarcomas. Indeed, so much confusion still surrounds the pathologic identification and classification of bone tumors that, even after microscopic examination, the clinician or surgeon often is in a quandary. Nor does submission of sections of tumor to several pathologists insure accuracy. Not infrequently the inability of different pathologists to agree on the character of a given tumor only serves to increase the uncertainty. That some pathologists should find themselves unable to agree with Ewing on the desirability of the designation "endothelioma," or on the origin of these growths from endothelial cells of blood vessels or lymph channels, is readily understandable. All pathologists have not had the same experience and all have not devoted the same amount of study to these tumors. But even if these aspects of the question are left aside as unsettled, no one who has had a considerable experience with tumors of bone and who has had the opportunity to examine and to treat with roentgen rays or radium a large number of such tumors can doubt the existence of a distinct group of bone tumors which exhibit the characteristics specified by Ewing.

The more one sees of bone tumors, the more one realizes the uncertainty of clini-

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cal diagnosis, and also of roentgenographic diagnosis, when the latter rests entirely on roentgenographic appearances. At best, diagnosis based on clinical or roentgenographic features is often uncertain. Since the fate of an extremity may be at stake, the greatest care in diagnosis is of the utmost importance, and the radiotherapeutic test should by all means be tried. Microscopic examination by an experienced pathologist yields accurate results in a high percentage of cases but, for various reasons, the pathologist cannot identify some bone tumors with certainty. Just as accurate as microscopic examination, and sometimes more accurate as a means of recognizing the essential character of a bone tumor, and especially that of endothelioma, is the effect of exposing such a growth to roentgen rays or radium, provided such exposure is carried out and the effect is observed by a radiologist who has made a careful study of the relative sensitiveness of different varieties of tumor. Still more accurate, however, is the combined use of microscopic inspection and the radiotherapeutic test. When the results of both methods point to endothelioma, the evidence becomes overwhelming. But when, as occasionally happens, the indications furnished by these two procedures conflict, the weight of evidence, as far as accuracy of diagnosis is concerned, seems to be in favor of the radiotherapeutic test. However great the knowledge and experience of the pathologist, he may be unable to identify a given tumor because the sections submitted are not truly representative or because degenerative cellular changes and inflammation may have so altered the appearance of the tissue as to make recognition well-nigh impossible. When, on the other hand, a tumor is exposed to roentgen rays or radium, if this is properly done, the entire neoplasm is subjected to the influence of the rays, and the rate of the ensuing regressive changes provides an invaluable means of identification. This is especially true when, as in the case of endothelioma of bone, the growth has a comparatively high degree of radiosensitiveness. With both methods, however, the greater the experience of the pathologist or radiologist, the greater the accuracy of their observations. Evidence of the radiosensitiveness of endothelioma is to be found in the rapid diminution in size of the neoplasm, relief from pain, and repair of the affected bone. On the whole, different endotheliomas exhibit less difference in sensitiveness than do most other tumors; in other words, the sensitiveness of different endotheliomas seems rather more uniform than that of other varieties of neoplasm.

Radiologists who have had extended experience with the treatment of bone tumors are familiar with the exceptional sensitiveness of endotheliomas. Yet many have become confirmed pessimists about the possibility of curing such neoplasms with roentgen rays or radium; some have even given up treating them altogether. As far as the permanent cure of osteogenic sarcoma and chondrosarcoma is concerned, pessimism is justified; it is well known that, although these two varieties of bone tumor may undergo partial retrogression under vigorous irradiation, although pain may diminish or disappear and the condition of the patient may improve for weeks or months, the neoplasm inevitably becomes active again and the patient dies. So true is this that when a case of supposed osteogenic sarcoma or chondrosarcoma is reported as cured, even when the diagnosis was based on microscopic examination, its authenticity may well be doubted. In view of the uncertainties of pathologic interpretation, it is probable that, in such a case, the tumor was an endothelioma. As for endothelioma, pessimism is warranted only to the extent that permanent cure is obtained in only a small percentage of cases and, as will be shown later, the reason why a permanent cure is not obtained in a larger proportion is because, when many patients come for treatment, metastasis already has occurred, although it may not become ap-

parent until later. When thoroughly treated, the primary tumor retrogresses completely and seldom becomes active again. Recurring activity of the primary growth is an absolute sign of inadequate treatment. In most cases, the metastatic deposits retrogress as rapidly as the primary tumor, but other deposits elsewhere sooner or later determine the issue.

The main purpose of this paper is to review a series of cases of endothelioma of bone. When this review was undertaken, the first difficulty that arose was to separate the cases into two groups: (1) proved cases, and (2) unproved cases. What constitutes proof? In view of the lack of agreement among pathologists, the mere fact that sections of a bone tumor have been subjected to microscopic examination can hardly be accepted as proof of its essential character. In several cases, a tumor which one pathologist had previously called a round cell sarcoma was classified as an endothelioma when the same sections were subsequently reviewed by a more experienced pathologist. Fortunately, in the majority of the cases included in this review, the microscopic examination of the neoplasms was conducted by a pathologist who has devoted much time to the study of tumors of bone. In a minority of the cases the microscopic examination was carried out by other pathologists.

One point which creates considerable confusion may here be mentioned. This is that different pathologists use different terms to designate tumors of the same variety. Thus, one neoplasm, which by one pathologist may be recorded as an endothelioma, may be set down as an hemangio-endothelioma by a second pathologist, either because the latter contends that the tumor arises from the endothelium of blood vessels or that there is evidence of differentiation; but sometimes this designation is used merely because the pathologist prefers the term "hemangio-endothelioma" or because, at the moment, the latter rather than the former term arises in his mind. Such looseness of expression is pernicious and undoubtedly accounts for some of the confusion which surrounds the classification of bone tumors.

Altogether, 52 cases are included in this study. Among these, 42 may be classed as proved if the verdict of an experienced pathologist is accepted as conclusive evidence of the character of a bone tumor. In the 10 remaining cases, biopsy was not made or the pathologist found himself unable to express an opinion.

PROVED CASES

Of the 42 patients included in this group, 26 were males and 16 were females. When the cases are distributed according to age, it is found that 7 of the patients were aged less than ten years, 11 from ten to twenty years, 11 from twenty to thirty years, 3 from thirty to forty years, 5 from forty to fifty years, 3 from fifty to sixty years, and 2 from sixty to seventy years.

The average duration of symptoms at the time the patients registered at the Clinic was 11.9 months for the 36 patients from whom a definite statement on this point could be obtained. Owing to the fallibility of human memory, the probable untrustworthiness of this information is realized, but it is given because, if this average lapse of time is added to the period of survival after treatment (in the cases in which the patients died), one has at least a rough idea of the average duration of the disease.

Another point on which stress cannot be laid is the significance of injury as a possible etiologic factor. Fourteen patients had sustained a definite injury but, in a certain proportion, a review of the circumstances makes it seem likely that the patient fell or otherwise injured himself because a bone had already been weakened by malignant changes. In the remaining cases, that is the majority, the patients could not recall any injury.

As presenting symptoms, 32 patients mentioned swelling, but in only 21 cases was it the outstanding complaint. Thirty-

nine patients complained of pain, but in only 30 cases was this the principal symptom. Only 6 patients admitted having had fever at any time; of course, this has little significance beyond showing that fever sufficient to attract attention is not common. In all probability, if the temperature of all the patients had been regularly ascertained, fever would have been discovered in a much larger proportion. Experience with patients suffering from disease commonly or usually accompanied by slight fever teaches that comparatively few of them are aware of the increase in temperature until the fact is drawn to their attention.

Pathologic fracture of the affected bone when the patient was first examined was found in only 6 cases; in another case, fracture occurred later. In 2 cases fracture related to neoplastic changes may have occurred, but unequivocal evidence could not be obtained.

As for the bones primarily affected by neoplastic changes, the femur was involved in 16 cases, the scapula in 6, the clavicle in 4, the ilium in 4, the humerus and mandible each in 2, and the radius, tibia, fibula, ribs, sacrum, skull, os calcis, astragalus, and distal phalanx of the thumb each in one.

At the time the patient underwent his first examination in the Clinic metastasis was found in 5 cases. Metastasis is known to have occurred later in 25 cases (including the 5 mentioned before), and in 9 additional cases the evidence points to subsequent metastasis, but it has been impossible to prove this absolutely. In the remaining 8 cases metastasis has not yet occurred, from two to twelve years since the patients were treated, and it seems likely that several, if not all 8, of these patients may be permanently cured.

Diagnosis. In connection with the comments previously made concerning accuracy of diagnosis, an accurate clinical diagnosis of endothelioma or Ewing's tumor was made in but 9 cases. In 3 additional cases, a clinical diagnosis of "probable endothelioma" or Ewing's tumor was made. By roentgenographic examination alone, without any knowledge of the clinical features, an accurate diagnosis was made in but 5 cases; in the remainder the tumor was regarded as osteogenic sarcoma, giant cell tumor, chronic osteomyelitis or tuberculosis. It must be remembered that many of the cases included in this study were first examined several years ago, when our knowledge of bone tumors was much less than it is today.

Microscopic examination of sections removed from the tumor brought an accurate diagnosis in 32 cases, and in 7 additional cases a diagnosis of hemangioendothelioma was made; these 7 cases should be added to the 32 preceding ones, because in reporting them as "hemangioendothelioma," the pathologist undoubtedly used this designation as a synonym for "endothelioma." In fact, this was usually implied by the addition, between parentheses, of the words "Ewing tumor." In only 3 cases, therefore, does a diagnosis based on microscopic examination appear to have been erroneous in that the pathologist regarded the neoplasm as of uncertain character, while the rate of regression after irradiation indicated it to be an endothelioma. In one case the pathologist's uncertainty was caused by degenerative changes within the tumor; in a second case the pathologist recorded the tumor as "malignant" without specifying its probable character. In all the so-called proved cases in which the primary tumor was not removed surgically, the response to roentgen therapy pointed to endothelioma. In several cases an antecedent diagnosis of sarcoma, round cell sarcoma, or malignant tumor had been made by another pathologist elsewhere.

Treatment and Results. In 11 of the 42 cases of this group the primary tumor was removed by surgical means. Of the 11 patients, 2 are known to be living at the present time, and one of these two does not believe the diagnosis could have been accurate because she is still alive. Curiously

enough, this belief has been fostered by the statements of other physicians. Moreover, the patient is the only one of the 11 from whom the primary tumor was surgically removed who did not receive postoperative treatment with roentgen rays or radium, or both. In her case the primary growth affected the distal phalanx of the thumb. The 9 other patients in this group are definitely known to have died, after an average postoperative period of survival of seventeen months (five to thirty-four months). Whether or not postoperative irradiation had any influence on the period of survival it would be impossible to say.

The extremity affected by the primary growth, or a portion of the extremity, was amputated in 4 cases, and in all 4 of these cases the patients are known to have died. Three of these patients survived for an average of twenty-five months; the date of death of the fourth patient could not be learned. Whether the eight months' difference in survival, to the apparent advantage of the cases in which amputation was performed, has any significance or whether this is but a coincidence, no one can be certain.

The only treatment given to 24 patients was roentgen irradiation, and 3 other patients received both roentgen and radium treatment. In all cases in which the primary tumor was exposed to roentgen rays, the method of irradiation was what we choose to call the method of multiple converging beams; this is an extension or elaboration of the principle of cross-fire whereby four, six, or eight or more beams of rays are made to converge on the neoplasm from as many different angles. Irrespective of the voltage at which the rays may be generated, this method produces a much greater regressive effect on the tumor than the usual plan of irradiation through two or three fields.

When the neoplasm is situated in an extremity and when, as is the case with most children and some adults, the extremity is small, roentgen rays generated at 135 kv. (peak) are preferred because a greater proportion of rays of this quality is absorbed by the diseased tissues of the patient rather than by the mattress, by the wood and metal of the treatment table or by the walls of the room. Rays generated at 200 kv. (peak) are reserved for the bulky tumors of adults, such as those which sometimes originate in the scapula, ilium or pubic bone, or in the upper part of the femur or humerus. However, it is not the bone involved, but the size of the neoplasm and the mass of tissue in which it is imbedded that must govern the quality of rays which should be used.

The quantitative dose per field depends on whether a course of treatment is given within a limited number of days or whether the tumor is treated by fractional irradiation. When the former method is employed, a second consideration influencing the dose applied to each field is the number of fields through which the growth is irradiated. A third element which should always be considered, regardless of the method of irradiation, is the age of the patient. Excessive irradiation of the rapidly growing bones and muscles of young children is known to retard or to arrest the growth of these structures. Moreover, in children and in adults excessive irradiation, while it may induce rapid regression of the tumor, may subsequently interfere with the deposition of callus and may lead to abnormal repair of the bone. These considerations should not deter the radiologist from treating tumors affecting the bony skeleton, but they should be carefully weighed in planning the treatment. Of course, a degree of abnormality in the repair of a bone is a small price to pay for a permanent cure.

Many of the patients whose cases are included in this report were treated with roentgen rays generated at 135 kv. (peak) and filtered through 6 mm. of aluminum. Others were treated with rays generated at 200 kv. and filtered through 0.75 mm. of copper and 1.0 mm. of aluminum. Still other patients, in whom a massive tumor projected from one surface of an extremity

or from the trunk, were treated with rays of comparatively long wave length on the proximal side and with rays of shorter wave length on the distal side.

Of the 24 patients who were treated with roentgen rays only, 7 are known to be living, twelve, two, two and a half, seven, five, three, and six years, respectively, since they registered at the Clinic. Six of these patients are perfectly well and are entirely free from any evidence of tumor. The seventh patient, a man aged fifty-eight, had an endothelioma of the upper part of the left femur, with pathologic fracture at the surgical neck. Under treatment this growth regressed rapidly and the diseased part of the bone underwent rapid repair. After he had received what was thought to be sufficient treatment, he was well for more than two years, when the malignant process again became active. Renewed treatment was again followed by rapid regression, and new bone is now forming rapidly at the site of the tumor. It is still too early to know if healing will be permanent. Curiously enough, microscopic examination of sections from the primary growth was reported as showing sarcoma, grade 3. The rate at which repair has taken place on two separate occasions cannot be reconciled with true sarcoma of bone but has been characteristic of endothelioma.

Among the patients treated with roentgen rays only, in a considerable proportion death is known to have resulted from metastasis without recurrence of the primary growth. In other cases, unfortunately, the information available is not sufficient to establish the percentage of the entire series in which this combination of circumstances occurred. Moreover, in some of the cases in which, after apparently complete regression, the primary tumor subsequently became active again, this was clearly due to insufficient or ill-planned treatment. The 18 patients who were treated only with roentgen rays and the date of whose death is known survived 23.9 months on the average. Two patients survived four and five years, respectively, before succumbing to metastasis. In the first of these 2 cases the prolonged period of survival appears to have been definitely related to irradiation. When treatment was instituted, the primary tumor in the right scapula was enormous and metastasis to the left ilium was present. Repeated irradiation by the method of converging beams caused the primary growth and the metastatic deposit in the left ilium to disappear, and these did not again become active at any time. More than three years later, massive metastasis in the right ilium developed. Additional treatment caused this large secondary tumor to retrogress at the same rate as had the primary growth and the first metastatic focus in the left ilium. Unfortunately, the patient's circumstances prevented thorough treatment; a few months later, multiple metastasis to the spine occurred, his general condition deteriorated rapidly, and he died. About the other patient who survived five years too little is known to enable one to estimate the possible relationship between roentgen therapy and survival.

UNPROVED CASES

In the 10 cases of this group biopsy was not performed and therefore many physicians would be unwilling to accept them as cases of endothelioma. The irony of this attitude is apparent since, even if the tumors in these cases had been subjected to microscopic examination by a pathologist, many other pathologists would not be willing to accept his interpretation. Yet in every other respect save this, all but one of the neoplasms presented the features described by Ewing, and their radiosensitiveness was characteristic of endothelioma. Five of the patients were males, 5 females. The respective ages of the male patients were fifty-six, seventy, two and a half, twenty-nine, and eighteen years, and the respective ages of the female patients, twenty-six, forty-nine, sixteen, thirteen and sixteen years. As for the bones primarily affected, the femur was involved in

3 cases, a rib in 2 cases, and the scapula, humerus, pubic bone, ilium, and clavicle in 1 case each. None of the patients was treated surgically, all being treated with roentgen rays only, by the method of multiple converging beams. In 3 cases the tumor has retrogressed completely, and the patients have been perfectly well and free from neoplastic manifestations for eleven, two and a half, and two years, respectively. A fourth patient, a man aged fifty-six, had a tumor of the right scapula measuring 11 by 13 cm., and at the same time a second tumor, probably metastatic, of the left ilium measuring 15 cm. in diameter. After being exposed three times at intervals of six weeks to multiple converging beams of rays generated at 200 kv. (peak) and filtered through 0.75 mm. of copper and 1.0 mm. of aluminum, both tumors disappeared completely and the patient remained well for ten years; he died after a short illness from a respiratory disturbance which was regarded as pneumonia. Lack of precise information about this last illness makes it impossible to be certain whether the respiratory disturbance represented a true pneumonia or a terminal effect of metastasis. In any event, he had survived ten years, and neither the primary tumor in the scapula nor the secondary tumor in the ilium had given any indication of renewed growth.

One of the 3 patients who are still living is a woman, aged twenty-six. When she registered at the Clinic, in April, 1934, she had been pregnant for several months. In the course of a pelvic examination the obstetrician discovered a large tumor projecting far into the left half of the pelvis and apparently arising from the ascending ramus of the pubic bone on the left side. A roentgenogram of the pelvis confirmed the obstetrician's findings and clearly showed the head of the fetus. The obstetrician felt that, since the pelvic projection of the tumor would render spontaneous delivery impossible, and since the growth might prove radiosensitive, roentgen treatment was indicated, even at the risk of destroying the life of the fetus. Four beams of rays generated at 200 kv. and filtered through 0.75 mm. of copper and 1.0 mm. of aluminum were directed toward the neoplasm from the anterior surface, and four additional beams from the posterior surface, the common center of all the beams corresponding as accurately as possible with the center of the tumor, as determined from roentgenograms. By the time a second similar course of treatment had been given, six weeks after the first, the portion of the growth that previously projected into the pelvis had retrogressed to such a degree that it could no longer be palpated. At term, the patient gave birth to a child weighing $3\frac{1}{2}$ pounds (1.6 kg.) which lived only one week. Evidently, irradiation had interfered with its intrauterine development; but the condition of the mother improved steadily, the tumor continued to diminish, and the affected portion of the left pubic bone underwent rapid repair. After confinement additional treatment was given.

The patient is now entirely well and the tumor has been completely replaced by solid bone.

SUMMARY

Many pathologists are still unable to recognize or unwilling to admit the identity of endothelioma of bone. So much confusion still surrounds the identification and classification of bone tumors that submission of sections to several pathologists does not insure accuracy.

Clinical diagnosis, and roentgenographic diagnosis when it rests entirely on roentgenographic appearances, are often inaccurate. Microscopic examination by a pathologist who has had exceptional experience with tumors of bone yields an accurate diagnosis in a large percentage of cases. Just as accurate, and sometimes more accurate, is the effect of roentgen rays or radium, when this effect is observed by a radiologist who has carefully studied the radiosensitiveness of different varieties of tumor. Still more accurate is the combina-

tion of microscopic inspection and the radiotherapeutic test.

Many radiologists have become pessimistic about the possibility of curing endothelioma of bone. It is true that only a small percentage of such tumors can be permanently cured; the reason why a large proportion cannot be cured is that metastasis already has occurred, although it may not become apparent until later. When thoroughly treated the primary tumor seldom recurs.

Forty-two "proved" cases are analyzed. An accurate clinical diagnosis had been made in 12 cases, and an accurate roentgenographic diagnosis in 5 cases. An accurate pathologic diagnosis was made in 39 cases.

The neoplasm involved the femur in 16 cases, the scapula in 6 cases, the clavicle in 4 cases, the ilium in 4 cases,* the humerus and mandible each in 2 cases, and the radius, tibia, ribs, sacrum, skull, os calcis, astragalus, and distal phalanx of the thumb each in one.

In 11 cases the primary tumor was removed surgically; 2 patients are still living. In 4 cases the affected extremity was amputated, but in all four the patients have died. In 24 cases the tumor was treated only with roentgen rays. Six of the 24 patients are living and free from malignant activity, twelve, two, two and a half, seven, five, three and six years, respectively. One is still living, but may not be entirely free from malignant activity.

In a considerable proportion of the patients who died death resulted from metastasis, in spite of the fact that the primary growth had disappeared and had not recurred.

Ten "unproved" cases are analyzed. The femur was involved in 3 cases, a rib in 2 cases, and the scapula, humerus, pubic bone, ilium, and clavicle each in one case. All patients were treated with roentgen rays only. Three patients are living and free from malignant activity eleven, two and a half and two years, respectively, since they were treated. A fourth patient who had two tumors, one of which was metastatic, lived ten years free from any sign of malignant activity and died after a short illness from what was thought to be pneumonia; neither the primary tumor in the scapula nor the secondary tumor in the ilium had given evidence of renewed activity.

* In one patient both the scapula and ilium were involved, and it was impossible to tell which was the primary tumor.

THE SPECIFICATION OF ROENTGENOGRAPHIC TECHNIQUE

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WHEN describing the technique for roentgenography of any particular region of the body, usually only four factors are specified: the distance, the time of exposure, the milliamperage, and the kilovoltage, in spite of the common knowledge that the use of such data by others will not yield duplicate results. A few other significant features are generally assumed or implied, such as an "average" patient, a filter of 1 millimeter of aluminum, "standard" processing, and a tube with a focus (linear, these days) to suit the load, and if a Potter-Bucky diaphragm is used, it is so indicated. The impossibility of transferring techniques by such methods from one machine to another is such a long standing experience that it seems to have been accepted by most roentgenologists as one of those things about which nothing can be done, and the problem of bettering the condition has been relegated to the background. Some realize that there is an important difference in the types of intensifying screens available so that the choice of one or the other may make a change of two or three times in the effectiveness of the exposure, but it is seldom that the intensification factor is mentioned. And the fact that the volume of matter irradiated as limited by cones and compression may change the amount of scattered radiation and so film density by an appreciable amount; that different types of cassette fronts transmit different amounts of radiation, and that films are not the same as to speed and contrast, both as among the products of different manufacturers, and as between issues of the same producer at different periods, are all ignored.

Roentgenography deals with units which are measurable and so the technical part of making the exposure is an engineering problem which should be susceptible of specification in relatively exact terms. It should be possible to so define techniques that the results can be duplicated, within the limitations of the apparatus used, on any generator in any laboratory. Probably no one will deny that it would be a great advance to be able, in some way, to apply to his own equipment the conditions specified by those who have made an intensive study of a particular body region, perhaps through the use of certain predetermined correction factors, and immediately obtain closely comparable results, and that the value of roentgenography would be greatly enhanced thereby. Such reward would certainly seem to warrant the great amount of work which is first necessary to investigate each of the individual factors and correlate their effects.

That the task is difficult and far from solution is, however, all too simple to demonstrate. Two factors, time and distance, are easy to measure and control. The patient may be classified as to thickness of part roentgenographed and type of excessive matter (heavy muscle or soft fat), and appropriate allowance made. Filters, cones and diaphragms need but to be mentioned. The influence of cassette fronts, intensifying screens, films and dark room technique is less easy to determine but still is not too hard to measure and once established remains relatively stable for each laboratory until a definite change is made. But the assumption that radiation quality and quantity may be specified in terms of kilovolts and milliamperes, while it may be true under special arrangement in a physics laboratory, is not justified by the conditions usually met with in a department of roentgenology. It is, of course, the radiation emitted by the tube, and not

the electrical characteristics of part of the generator system, which is used in making the roentgenogram, and unless the former can be accurately described in terms of the latter the specification of technique in kilovolts and milliamperes has no precise significance in translating work from one machine to another. This does not mean that such terms are entirely useless, for there must be some language to describe changes of setting on a generator and it may be just as suitable to call the one factor kilovolts as to designate it by button positions or primary volts, and milliamperes has greater meaning to most than the filament setting, but what is needed is a way of connecting these everyday units with some primary standard of tube output which will have universal significance.

The essential elements of roentgen-ray output are (1) the magnitude and the wave form of the potential effective between the cathode and anode; (2) the magnitude and wave form of the current through the tube; (3) the phase relationship between these two if it be other than unity, and (4) the filtering of the radiation. There are a large number of ways in which each of these elements may be affected in one way or another. Aside from the selective ones of autotransformer and filament setting, the following factors which influence the roentgen-ray output and may be the source of differences between various installations are met with in the ordinary diagnostic laboratories:

A. Those affecting the voltage through the tube:
   - Resistance drop of the main leads.
   - Resistance drop in the controls and transformer.
   - Transformer design, step-up ratio and capacity.
   - Type of rectification, whether self-rectified, mechanical or valve.
   - Degree of rectification: whether single or four valve; if mechanical, the percentage rectified.
   - Rectification losses; these vary with the design of the cross arms, if mechanical, or with the design of the rectifying tubes and the setting of the filament in valve apparatus.

B. Those affecting the high tension current through the tube:
   - Type of stabilizer used, if any, and its adjustment.
   - Losses of current which have been measured by the milliammeter; these will be of greater or less influence as the meter is more distant or nearer the tube:
     - Leakage over insulators, posts, brackets and across switches.
     - Corona loss from sharp points such as on switches, terminals of the aerial system, and frayed points on cord reel wires.
     - Corona loss from aerial conductors as influenced by the size and spacing of the tubing and of the cord reel wires.

C. Hidden electrical factors:
   - Wave form of the voltage, including its general form and superimposed regular or transient surges.
   - Wave form of the current, including its general form and superimposed regular or transient surges.
   - The wave form of both the potential and the current is influenced by most of the items listed under A and some of those under D.
   - Type of main switch used, i.e., whether or not it always makes and breaks at zero potential, thus influencing transient surges and affecting the total exposure for rapid shots.
   - Phase relationship (power factor) of the high tension voltage and current as varied by the design of the control and transformer, the rectifying system, and the capacitance of the high tension system as determined by geometrical arrangement of the aerial leads.

D. Tube factors:
   Design of bulb and envelope as it affects the building up and distribution of scattered electrons (the grid effect).
   Design of the component parts of the tube as it may affect the electrical characteristics of the high tension circuit (wave form, surges and power factor).
   Degree of vacuum of the tube and kind of residual gas.
   Slope of the target face and direction of the beam of rays with reference to the face of the anode.
   Degree of pitting and cracking of the target.
   Thickness and kind of material of the tube wall exit portal.
   Filtering by a film of tungsten and/or copper on the tube wall vaporized from overloading the target.
   Tube design with reference to the relationship of saturation voltage at various current loads.

In addition to these there are probably other factors which have been overlooked which also play a part in varying the roentgen-ray output as between different laboratories. Undoubtedly, the effect of many of these sources is trivial and of no significance from a practical roentgenographic standpoint, but the decision as to which should and which should not be considered noteworthy is safest determined from actual experiment and test.

When specifying technique by electrical terms, only a small part of these variables is controlled. Thus if one has a good milliammeter of proper type and accurate calibration mounted close to the roentgen tube, he may be assured that many of the differences caused by high tension current losses are eliminated so far as comparing that phase of electrical input to the tube with another similar installation is concerned. But even that is not of great significance for milliamperes do not mean the same thing on all generators from the standpoint of roentgen-ray intensity; even with all other factors theoretically the same, 20 milliamperes as measured on a self-rectified machine may be expected to yield a different radiation intensity from 20 milliamperes on a four valve circuit. Taylor, Singer and Stoneburner[25] found in their work in the therapeutic range that effective milliamperes as measured by a surge protected and shielded A.C. milliammeter was a more accurate indicator of roentgen-ray intensity at a given voltage than average milliamperes as measured by the customary D.C. meter, and that when suitable correction was made for the suppressed half of the cycle the results from half-wave generators were closely comparable to those from full wave and constant potential apparatus.

That the measurement of voltage is not reliable is attested by the numerous methods of establishing this value which have been used or proposed. These include:

Spark gap measurements:
   Between blunt points.
   Between sharp points.
   Between a point and a plate.
   Between spheres of various diameters.
Computation from the measured primary voltage and the step-up ratio of the high tension transformer.
Computation from minimum wave length of the roentgen-ray output as determined spectrometrically.
Electrostatic voltmeters of torsion, attracted disk, or vane type.
The Kirkpatrick rotary voltmeter.
Resistance voltmeters:
   Kilovolt r.m.s. meter of Taylor.
   Thyratron peak voltmeter.
   Oscillographic records.

Spark-gap measurements between anything but highly polished spheres are so grossly inaccurate that they have been practically abandoned, but even the present method of using sphere gaps is not sufficiently accurate as a reliable measure for roentgenographic purposes. When used to measure voltage at high milliamperage and the balls are gradually brought closer

together in steps between which a short exposure is made, the conditions make for surges on the first impulses which establish the spark-over distance and are a faulty indication of the peak value of the remainder of the impulses. On the other hand, when at low milliamperage the current is continuously passed through the roentgen tube while the spheres are approximated, the stresses and corona (which latter is nearly always present to a variable degree between the spheres commonly used in most laboratories) tend to ionize the air and permit spark-over at a greater distance than when there is no ionization; the magnitude of this error may vary considerably, depending upon the smoothness of the sphere surfaces, their diameter, the speed with which they are brought together, and the temperature, pressure and rate of circulation of the air. The unreliability of sphere-gap measurements was demonstrated some time ago in this laboratory when an opportunity was presented to check a calibration made with one set of spheres against that with another size. The curves relating sphere-gap voltage to autotransformer setting at various milliamperages as obtained with one set had no discernible relationship to those obtained with the others. Not only were the indicated voltages at identical settings all different but these curves showed no definite correlation. Naturally no confidence could be placed in the results.

The thyratron peak voltmeter[33] eliminates the errors from corona ionization and differences of atmospheric conditions and so is a more reliable way than the open gap of measuring the peak value. However, as with the sphere gap, it suffers from two serious fundamental objections: first, it indicates only the very highest potential which all too frequently is a transient surge bearing no relationship to the integrated peak value of the rest of the impulses; and second, even the average peak voltage is not a significant measure of the radiation which will be emitted by a tube because of the wide differences in wave form. For it is possible that two machines of different wave form may be set to the same milliamperes and peak voltage and give an output of radiation differing in intensity by as much as 100 per cent with a corresponding wide difference in the quality.[29]

The Kirkpatrick rotary voltmeter[12] measures the integrated effect of a large number of impulses and so eliminates the error from transient surges as well as the troubles with open gap measurements. The device draws no current from the line, is accurate yet rugged, and is relatively inexpensive; if the peak voltage must be known it would seem that this would be the most reliable instrument to use. But except on constant potential direct current generators, the peak voltage is not of great meaning. By the addition of a phase shifting transformer the Kirkpatrick voltmeter may be used to plot out the potential wave form which, from this standpoint, puts it also in the class of oscillographic devices for indicating potential.

Oscillographic records of the potential are very important but have their greatest usefulness in an engineering or physics laboratory to analyze and study the various problems from a theoretical standpoint. Even ignoring the impracticality of their use in the field, the results obtained are not readily to be translated into terms which are convenient in specifying roentgenographic technique. The peak voltage may be readily obtained from them but this is not the significant indicator of roentgen-ray quality and a method of deriving a useful value from the curve of voltage distribution has yet to be worked out.

Computation of a high-tension voltage value from the step-up ratio of the roentgen transformer and measured primary voltage is a crude method which, although it may be no worse and perhaps may even be of more significance than some of the other methods used, has not been proved to be satisfactory for the purpose of a primary standard. Perhaps the primary voltage may prove the best secondary standard for

describing differences in technique on the same machine but this must be correlated in some way with a primary standard which can be used to carry the technique from one machine to another. Computation of peak voltage from minimum wave length is an accurate method of determining that value in a physics laboratory which, when carefully carried out, eliminates many of the errors in other methods, but it is not practical for use in the field and, as with other measures of peak voltage the results are not of adequate meaning in specifying roentgen-ray quality. The conventional electrostatic voltmeters, while they might give a reading in the form of root-mean-square voltage which would be of use, have so far been such delicate instruments and subject to so many sources of error that they have not been satisfactory outside of the carefully controlled conditions of a physics laboratory.

The remaining method of determining voltage consists of D.C. and A.C. voltmeters used in conjunction with a 150 megohm noninductive shielded resistor placed across the high tension leads to the tube measuring average and effective (r.m.s.) voltages respectively.[22] Results obtained are far more significant than any other as might be anticipated from a consideration of the conditions. The rays given off by the tube are related to the instantaneous values of voltage throughout each complete impulse; the film integrates these rays and gives a density which is related to the sum of those portions which are not filtered out by the conditions of the exposure, and not to the most penetrating portions derived from the peak voltage values. Hence it is to be expected that, if there be any value at all in voltage as a determiner of roentgen-ray quality, it might lie in a method of measuring which would integrate the various instantaneous potentials rather than indicate a maximum value. The work of Taylor and his associates[24] with measuring kilovolts-effective has demonstrated that this is true and that the absorption curves of the output of generators of different wave form were nearly alike when taken at the same kilovolt-effective potential although the peak potentials were quite dissimilar. His work was done in the therapeutic range but it is reasonable to expect that a similar result would be obtained were it extended to diagnostic values. Although the resistors which are necessary in measuring kv. r.m.s. are so expensive as to prohibit their installation in all but a few financially fortunate laboratories, the unit could serve as a primary standard in the possession of some central agency and be utilized to calibrate individual machines by autotransformer buttons or primary voltmeter readings in the same way that these machines are now "calibrated" by the less significant sphere-gaps.

So it is seen that not only is the present method of measuring voltage by sphere-gap subject to inaccuracies, but also that the peak voltage, no matter in what way it may be determined, is not a good measure of roentgenographic quality. Kilovolts-effective may prove to be a satisfactory means of specifying this factor but a consideration of those elements listed under "hidden electrical factors" and "tube factors" in the tabulation of the sources of differences between various installations suggests that a primary standard for roentgen-ray quality may not be found in defining the electrical input to the tube. For one thing, the phase relationship between current and voltage may not always be the same and if it is not, the tube output is going to change when the power factor changes even though the kilovolts-effective and milliamperes remain the same. And the filtering of the rays between the point of generation and the outside of the bulb is going to vary from one situation to another. It has been shown[37] that the intensity of radiation in the plane perpendicular to the anode face and including the central ray increases from a low value in the direction of the projection of the target face to a maximum at about 30° from this, and that the quality of the

radiation likewise varies with the direction of the beam, being softest in the direction of maximum intensity and becoming progressively harder as the radiation is weaker. It might be a fair assumption, therefore, that the radiation in the direction of the central ray would be different both as to quality and quantity from a tube of 20° slope than from one of 45° or of 10°, even assuming it to be possible to apply the same electrical conditions. Pitting and cracking of the target would be expected to increase this dissimilarity, the change from this cause being more marked with tubes of steeper anode slope. The rays are further filtered by the envelope of the tube, both the composition of the glass and the thickness of the wall exerting their effect. And any deposit of copper or tungsten on the wall of the exit portal will have a definite effect for, although the thickness of the layer might be minute, the mass absorption coefficient of the metals, especially of the latter, is high so that only a thin layer is required to change the beam. For these reasons, even though the electrical input to the roentgen tube is accurately known, it may be that these data will be insufficient to specify the radiation in precise, universally applicable terms.

All these considerations would lead to the conclusion that it is not volts and milliamperes which must be known but some unit of quality and quantity of the emitted radiation. The problem of measuring roentgen radiation has been approached by those interested in defining therapeutic techniques, with results which may prove acceptable when extended to diagnostic radiation. Perhaps the established standard of ionization measurements for roentgen-ray quantities may not be a direct indication of photographic effectiveness, but since this has been developed at considerable effort it would seem that the first important step toward a primary roentgenographic standard is an investigation of the relationship between roentgen units and film density. This must be extended throughout the range of conditions used in roentgenography from the shortest exposures at high intensity to the long time, low current exposures, and may necessitate the design of special ionization chambers. A recent change in the design of the ionization chamber of one of the commercially marketed roentgenometers has reduced a source of error when it was employed to measure long wave radiation so that now these instruments may be used with confidence for most of the diagnostic radiations which have been filtered by 0.5 mm. of aluminum or more. Investigations which may be carried out on the very soft radiation from unfiltered, low voltage output or on scattered radiation may make use of the special mesh chamber devised by Quimby et al.[18]

Specification of quality would appear to be a more difficult question, and may require the careful investigation of the possibilities as a roentgenographic standard of the half-value layer, the effective wave length and the absorption curve, each of which has its advantages and limitations. Half-value layer by Meyer's photographic method at first sight would seem to be the most desirable, for it may be rapidly and simply evaluated under a wide range of conditions, including the short exposures at high milliamperes (the density of the film may be changed by varying the distance without disturbing the other technical factors of exposure) and the tools necessary are so simple they may be purchased for a small sum or be made by nearly any laboratory. But, as Wilsey[36] has shown, the results obtained are not precise under ordinary circumstances due to the many factors connected with photographic photometry which are not, at present, standardized. Thus the figure obtained on process film (as recommended) would not be the same as on roentgen-ray or other film; in fact the different brands of roentgen film on the market and the changes which appear from time to time in each brand are apt to lead to discordant results. The technique of development also plays its part: the formula, age, concen-

tration, temperature and time of processing all being sources of variation in the results. The magnitude of the discrepancies which thus enter and their importance from a practical standpoint is a matter which should be investigated for it may be possible to standardize the conditions without entailing too much added expense and inconvenience and obtain results which would be significant for the purpose.

Half-value layer by ionization is not subject to such sources of error and is rather easily obtained once the expensive roentgenometer is available—those laboratories which do not undertake therapy may share it through mutual ownership by, or rental from, some central agency; its extension to the diagnostic range offers possibilities for investigation. Effective wave length by the Duane method is also easy to obtain, requiring only two readings at each setting. One objection to both these methods, however, is that they require the measurement of unfiltered radiation and as the thimble chamber roentgenometers have an unknown error from the wall effect for the very soft beam so obtained, the results are not apt to be of precise significance. Effective wave length by the bracket method would eliminate this trouble, for both readings are made through a filter which cuts out the very longest waves and leaves a beam which can be measured accurately by the regular thimble chambers.

The outstanding objection to the use of a single figure in specifying quality, whether it be by half-value layer or effective wave length, is that it measures a composite result which may be achieved from widely differing conditions. Thus Wilsey[35] shows that the same effective wave length of 0.23 Å is realized from 86 kv. radiation filtered by 0.58 mm. of copper, and 152 kv. radiation through 0.28 mm.; i.e., that both these heterogeneous beams are absorbed to the same extent by a slight increase in the filter as would be monochromatic radiation of 0.23 Å. Although the fact has not been demonstrated, it would hardly be expected that each beam would yield identical photographic results, for the radiation produced at the higher voltage contains short rays which are not even generated at the lower. It would seem possible, however, that if a standard prefilter of say 2 or 5 mm. or perhaps 7 mm. of aluminum was adopted as standard this objection would be overcome and the use of half-value layer or effective wave length might prove satisfactory for the purpose. Probably the higher prefilter would be the best, for its use would reduce the effect of the longer wave lengths, and it seems to be the presence of varying proportions of these long waves in the beam which accounts for some of the annoying differences observed in both quality and quantity under different conditions, such as when comparing two different roentgen tubes operated on the same equipment. The use of a high prefilter is further justified by the fact that the body of the patient acts as a filter of at least an equivalent amount for nearly all roentgenographic exposures, and thus the beam evaluated would be more nearly like that affecting the film.

The relative transmission curve is the best means at present for demonstrating differences between radiation qualities, but in itself is not a practical method of specifying roentgenographic technique. One would hardly anticipate that one of the factors used for a certain exposure could be published as a curve, or table from which the curve could be constructed, and expect others to try to match it in order to achieve the same roentgenogram; to be of practical use, whatever quality unit is adopted must be in the form of a few simple numerals, although other data, such as a prescribed prefilter, may be assumed or defined as part of the standard conditions. To meet this desideratum, Taylor and Singer[23] have suggested the matching of a relative transmission curve as obtained in the field with one of a group of standard curves from a constant potential direct

current generator by shifting the graph parallel to the axes and designating the match and shift by numerals. Thus, if a curve from certain field conditions can be made to match the standard for 60 kv. constant potential by shifting it over on the graph a distance corresponding to 0.8 mm. of aluminum, the quality would be indicated as 60 kv. constant potential plus 0.8 mm. of aluminum. This method offers a hope for indicating an absorption curve in simple numerals so that its possibilities in the diagnostic range should be thoroughly investigated. However, an experience with this at this laboratory seems to cast some doubt upon its practicability: Absorption curves were obtained from different roentgen tubes on the same generator which, from their shape and curvature, should have found a match either with one of their standard curves or with some interpolated position between them, but considerable effort to establish this was without avail. During the attempt, it was also discovered that trying to match curves by drawing them on transparent graph paper and shifting one over the other was an inconvenient and tedious task under the conditions of an ordinary roentgen department which might prove a handicap to the use of such a method. Perhaps the failure to obtain a match was the fault of the operator, but, on the other hand, it does seem as though the distribution of wave lengths in beams from different types of rectifiers and roentgen tubes would not be the same as from a constant potential source and therefore the absorption curves would not be similar.

With all ionization measurements there is, at present, a drawback in that a comparatively long exposure is required which limits their use at high power because of the strain on the roentgen tube. Readings taken at this laboratory at 25 cm. distance with a 1 c.c. thimble chamber roentgenometer required from 60 to 200 ma-sec. at potentials ranging down to around 40 kv. through as light a filter as 0.5 mm. of aluminum in order to obtain a displacement on the instrument of a satisfactory amount, while in taking an absorption curve at a medium voltage as high as 150 seconds' exposure at 8 ma. was necessary to go through 10 mm. of aluminum. Thus, the use of the customary 1 c.c. ionization chamber for the determination of half-value layer, effective wave length, or an absorption curve is practically restricted to conditions of low milliamperage lest the roentgen tube be ruined. Roentgenometers can be obtained, however, with larger chambers, even up to as large as 500 c.c. capacity, and one of these might solve this fault, although in order to obtain an absorption curve at flash techniques where variation in the time of exposure would have a significant effect, it might be necessary to have an assortment of chambers of various sizes and ranges. Such considerations are only some more of the problems which need to be tested by trying them out to discover just what is needed.

One further possibility of specifying roentgenographic output should be mentioned: that of Weyl and Warren[31] based upon the work of Bronkhorst.[3] Although their attention was directed primarily to roentgenography of the chest, their method, should it prove practicable, might be easily extended to other body regions. Bronkhorst exposed an aluminum ladder and plotted the density under each step as a function of the thickness of the step. The complete ladder is abridged by Warren to a small block having only three steps, of $\frac{3}{8}$, $\frac{1}{2}$, and $\frac{5}{8}$ inch thickness, respectively. On chest films this is placed in a corner of the cassette above the patient's shoulder where the incident radiation is not intercepted by the body, and casts its shadow on each film. When developed, the measured density under each step is a record of the conditions used as to both quality and quantity of radiation and includes the effect of all the other factors such as screens, films and processing. These latter may not be evaluated separately from the record but the authors argue well that it is unnecessary to know all the variables for it is the finished film which must be standard-

ized. Thus, in their book they specify that the technique of exposure for a chest of measured thickness should be such that the densities under the three steps should be certain stated values. Complete specification of the technique thus takes the form of chest thickness versus three density values, with a small table covering the entire range, and it is unnecessary to indicate the auxiliary factors. This method at first sight would seem to be the best of all, for the ladder is very simple and inexpensive to make, and for those who are unable to afford a densitometer it may prove possible to obtain sufficiently accurate results by visual comparison of the density values with an inexpensive standard density scale; also all the auxiliary factors are automatically cared for and so the designation of technique is greatly simplified; and, finally, the data lend themselves to satisfactory publication by stating only a few numerals. However, because of the great number of difficulties standing in the way of precise photometry by the photographic method one would hesitate to be too optimistic over its possibilities until it is thoroughly tried out and studied. At this laboratory results achieved on a group of a few hundred chests have so far not been in accord with those published by Warren, although further study and more data may serve to indicate how a better correlation can be realized. Certainly this means of defining exposure conditions should be extensively studied by a large number of widely scattered laboratories that it may have the rigorous test which its promise warrants.

Thus, it is seen that defining roentgenographic technique in terms of the factors now commonly used is not adequate to permit others to duplicate the results. The greatest error appears to lie in using the term kilovolts, for this unit is not satisfactorily measured in the usual roentgen department, and, further, the peak kilovoltage is not a good measure of roentgen-ray quality due to other factors which enter in. Thus, some unit for measuring roentgen-ray output, rather than electrical input to the roentgen tube, is needed to adequately define techniques. The roentgen, the adopted unit of roentgen-ray quantity in the field of therapeutics, may prove useful when extended to the diagnostic range, but a satisfactory means of denoting the radiation quality remains to be found. Half-value layer and effective wave length by either the bracket or the Duane method are all relatively easy to measure but have certain limitations and objections which must first be eliminated before they will prove acceptable. The long exposures required would seem to be a handicap to the use of the absorption curve even should it prove possible to overcome the other difficulties and be easy to designate the results in simple numerals. Effective wave length, after a standard prefiltering which would eliminate the greater portion of the long wave components, would appear to be the most promising of the units obtained by ionization. Photographic evaluation of half-value layer is intriguing but the sources of error are so numerous that the conditions must be more rigidly defined than at present before the results will be standard. The direct specification of technique covering all factors by means of film densities under a small aluminum ladder offers such great promise in spite of apparent difficulties in the way of photographic photometry that it should receive an earnest consideration and thorough investigation by all who are interested in solving the problem of stating roentgenographic technique in terms which will have universal application. It is not the purpose of this paper to recommend the use of any particular units for this purpose, but rather to point out the reasons for the failure of the present terms and to urge that those interested undertake a comprehensive investigation of some restricted phase of the problem that the knowledge so obtained may ultimately lead to the realization of success.

Much of the material presented in this paper represents an extension to roent-

genography of the work which has been done in the field of standardization of units for therapeutic purposes, for it is possible that the results obtained there may prove quite suitable for the latter purpose. However, because of the different requirements of the two fields, it is not certain that methods which are satisfactory in treatment will be adequate for the diagnostic problems; although the radiation used, roentgen rays, is fundamentally the same in both fields, it differs considerably in quality, quantity, and application, as may be realized by considering that in the one case large doses of relatively homogeneous radiation are directed to a material which is, for practical purposes, somewhat insensitive to the rays, while in the other case minute doses of radiation with a wide range of wave lengths is directed to a medium which is extremely sensitive. Therefore, although a great amount of valuable information may be derived from published papers dealing with the problems of units for roentgen therapy, it is not safe to depend upon the results achieved in that field for a satisfactory conclusion in roentgenography. The references cited have been drawn upon heavily for a large part of the evidence and conclusions used herein and are compiled to facilitate the studies of others who may take up work upon the problem presented.

SUMMARY

After pointing out that roentgenographic techniques are not completely specified by the four factors usually used of distance, time, milliamperage and kilovoltage, issue is taken with the custom of defining roentgen rays in the terms of electrical input to the tube. Factors which enter into producing a difference in roentgen-ray output are tabulated. Attention is called to the difficulty of satisfactorily evaluating the tube potentials and the various methods of measuring this element are discussed in the light of their limitation as a determiner of roentgen-ray quality, leading to the conclusion that some units based upon tube output must be adopted before techniques for roentgenography of the various parts of the body can be specified in terms which will have universal significance.

Methods of measuring the quantity and quality output of roentgen tubes are discussed from the standpoint of their usefulness and limitations as roentgenographic units and some of the problems to be investigated before a satisfactory solution can be reached are pointed out.

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THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

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Twenty-third Annual Meeting, 1938: To be announced.

EDITORIALS

ARTHUR CARLISLE CHRISTIE, M.D.

ELBERT HUBBARD has said that "the reward for good work is more work." The truth of Hubbard's observation is well illustrated by the career of Arthur Carlisle Christie.

Christie was born December 29, 1879. It is said on good authority that he early manifested a superlative degree of energy, which has remained an outstanding characteristic throughout his life. Neither the number nor the magnitude of the jobs he is called upon to perform seems to daunt or disconcert him in the slightest. Like an expert juggler he can keep half a dozen things going at the same time, any one of which would appall the average individual. A proof of this may be cited the fact that at the present time, in addition to active participation in the professional and other activities of a large radiological clinic, and his manifold duties as President of the Fifth International Congress of Radiology, he is also Chairman of the Board of Trustees of a large university; Chairman of the Board of a large home for children; President of the American Board of Radiology; Chairman of the Inter-Society Radiological Committee; President of the Board of the Central Admitting Bureau for Hospitals of Washington; Chancellor of the American College of Radiology; Director of Group Hospitalization of Washington, and a Director of the Washington Board of Trade and Chairman of its Public Health Committee.

The above does not by any means exhaust the list of his activities nor does it indicate that he is at the moment unusually busy. There has been scarcely a time in the past thirty years when he has not been as fully occupied with various professional and organizational activities as he is now. To merely enumerate them would be tiresome, and to tell their whole story would require volumes.

For instance, much of interest could be written in connection with his military service, particularly with respect to the period when he had general charge of roentgen-ray work for the American Army during the World War. Again, his work as a member of the Committee on the Costs of Medical Care would make a story of absorbing interest, as would also his efforts to improve the American Journal of Roentgenology and Radium Therapy during the several years he was its Editor.

Of the many honors (or should we say opportunities for service) which have come to Dr. Christie, not one has to our knowledge been of his own seeking. Gifted with a keen mind, a pleasing personality, and a remarkable aptitude for cooperation, they have come to him spontaneously. His facility of expression has made him much sought after both as a speaker and writer. This has added to his popularity and widened his acquaintance both at home and abroad. Only recently he gave, on invitation, the Silvanus Thompson Memorial Lecture in London—a signal honor for an American.

One is always tempted to moralize on a life so replete with accomplishment as that of Dr. Christie, for, after all, such a life is rather rare. Had Elbert Hubbard been a good physiologist, he might have attempted to explain his proverb which introduces this brief sketch by saying that good work is largely a matter of endocrine function. Whatever may be the explanation, it is quite certain that so long as Radiology has among its devotees such men as Christie, it will maintain an honorable place in the galaxy of medical specialties. With his ability to command the wholehearted support of organized radiology, the success of the Fifth International Congress of Radiology, the first to be held in America, is assured.

T. A. G.

Arthur Carlisle Christie

President of the Fifth International Congress
of Radiology, 1937

PHYSICAL AND BIOLOGICAL DOSAGE IN RADIATION THERAPY

ONE of the most noteworthy contributions of the First International Congress of Radiology, which was held in London in 1925, was to appoint a committee from various scientific bodies throughout the world to study the question of roentgen-ray measurement, thus laying the basis for the introduction of international units and standards. At the subsequent International Congresses at Stockholm, Paris and Zurich, this committee very cautiously, step by step, made recommendations which aimed to and in most instances have created order in a field of extremely difficult problems. As a result of such laborious effort, the clinical radiologist was placed in the more and more fortunate situation of being able to administer roentgen treatment to a certain patient or a certain lesion with a dose which was as carefully and accurately measured as is customary in other less abstract branches of medicine. Perhaps a little too much emphasis was laid on the physical side and the biological observations were often subjugated to physical standards, but this was gladly overlooked in view of the fact that the radiation prescription has become greatly simplified and above all reproducible. The texts of the International Recommendations agreed upon by the Standardization Committee at the various congresses were therefore gladly accepted, and they were carried out according to the best clinical applicability.

With the advent of supervoltage roentgen therapy and the more recent progress in radium therapy, however, certain new observations were made, both from the physical and the biological standpoint, which seem to necessitate a reconsideration of many of the problems related chiefly to the dosage. To the British X-ray and Radium Units Committee belongs the honor, as has been the occasion so many times in the past, of having initiated a series of tentative suggestions which will be submitted to the International Committee for Radiological Units at the Fifth International Congress of Radiology at Chicago in September, 1937,* and which aim toward a redrafting of the former Recommendations. In order to preserve continuity, the suggestions were made along lines which avoid the introduction of radical changes. They concern, in the main, the redefinition, or rewording of the definition, of the roentgen so as to be applicable to supervoltage roentgen rays and the adoption of the unit roentgen for the measurement of the gamma rays of radium. All proposals, as one may expect, are purely physical in nature and in this regard they constitute a logical sequence to prior procedures.

In discussing the specifications of the conditions of treatment, however, for the first time a differentiation is made between the physical dose and what one may call the biological dose. Thus paragraph 6 of Section B reads: "In the description of the conditions of X-ray treatments, distinction should be made between the dose as measured in air (air-dose) and that rereceived by the irradiated tissue (tissue-dose), the unit being designated 'r' in the former case and 'r'' in the latter.

"The specification of the conditions should also include statements of:—I. *Dose.* The total quantity of radiation in röntgens (r') estimated to have been received by the lesion." And the same recommendation is made concerning the gamma rays of radium in paragraph 7, I. Such differentiation of dosage must indeed form a happy desideratum to every clinical thinker. For, evidently, we cannot work in practical therapy with rigidly defined absolute physical units by ignoring the biological reactions which take place as the result of the greater or lesser energy absorption of the same units under various

* International Recommendations for Radiological Units. *Brit. J. Radiol.*, June, 1937, *10*, 437–444.

circumstances. Yet one cannot conceal the perhaps overzealous fear that the introduction of a second roentgen unit (r′) in a biological sense may give rise to some confusion, especially if certain more complex, as, for example, the mixed form of irradiation is employed. That a distinction must be made between the roentgen unit (r)

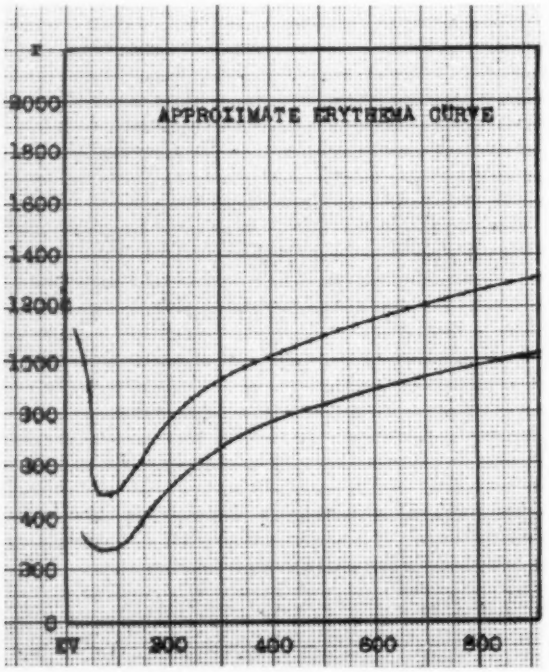

Fig. 1. Showing relationship of the physical (r) to the biological (s.e.d.) dose up to 900 kv. equivalent. $T = 20$ r/min., $F = 20 \times 20$ cm. Treatment in one seance. Upper curve: r, on patient's skin; lower curve: r, in air. These curves are approximate and some minor changes may be necessary.

as measured in air and as measured on the patient's skin (with back-scattering) there can be no doubt. Some symbol may even be used to make this distinction more apparent. But the introduction of the same quantitative physical unit for the expression of the tissue dose, which in most instances is estimated by biological criteria, may lead to situations of intricate character which may tend to reduce rather than increase the clinical value of the roentgen as a whole.

For the same reason, the suggestion is made—and the writer hopes that he will not appear too bold in doing so—that the entire problem of biological dosage be detached from the physical dosage and that it be dealt with *in extenso* under a separate section. It is then recommended that until some sort of energy absorption unit is devised which must form the ultimate goal, the "skin erythema dose" be used as the basic unit of biological dosage and that the physical dose (r) be coördinated with the biological dose (s.e.d.) over all the voltage ranges, including the gamma rays of radium. Figure 1, for example, shows the relationship up to 700 kv. equivalent, and Lauritsen* theoretically calculated it up to 2,000 kv., that is, in the neighborhood of the gamma rays of radium. In this manner, the erythema curve at once acquires a definite, physically measurable value as far as the surface dose is concerned, and the "tissue dose" at any depth could be designated in percentage of that surface dose. Two practical examples, representing opposite extremes, will be cited to illustrate to better advantage the significance of this procedure. It is assumed, for instance, that a carcinoma of the skin and a carcinoma of the uterine cervix are being irradiated each with 5 skin erythema doses in one seance, but the first with a combination of 1 s.e.d. with 500 kv. equivalent and 4 s.e.d. with 85 kv. equivalent, and the second with a combination of 1 s.e.d. with 500 kv. equivalent and 4 s.e.d. with gamma rays of radium in contact. In the first case, the 5 s.e.d. would represent a dose of from 2,500 to 4,000 r′ (depending on the size of fields), whereas in the second, if the new recommendations concerning the specifications of gamma-ray treatments are employed, the 5 s.e.d. would represent a dose which is certainly in excess of 5,000 r′. But even if one uses a simple combination of irradiation with deep (200 kv. equivalent) and supervoltage (e.g. 900 kv. equivalent) roentgen rays, the skin erythema dose may vary from 800 to 1,300 r′, according to how great a fraction was administered of the

* Lauritsen, C. C. Am. J. Roentgenol. & Rad. Therapy, 1933, *30*, 380–387; 529–532.

one or the other type of radiation. If to this be added the effect of the intensity factor and in the fractionated, protracted methods the influence of the time factor, then the tissue dose as expressed in r′ may assume almost any numerical figure which would make the clinical estimation of the dosage most difficult.

The introduction of the skin erythema dose as the biological unit in the above sense and its standardized coördination with the physical dose helps to correct this situation. The tissue dose, or the total amount of radiation which must be given to a certain lesion, is always expressed in the same magnitude of the unit (percentage of the skin erythema dose) throughout the entire voltage range, including the gamma rays, and the physical dose to be administered is, then, read from the coördination curves for each particular voltage range employed. Such procedure furthermore has the advantage that it tends to harmonize the various biological units which are used nowadays in the current clinical practice, as, for example, the threshold erythema dose, the skin tolerance dose, etc.

For medical purposes, at least four factors must be considered, and more or less standardized, to make the coördination of the physical dose (r) and the biological dose (S.E.D.) possible. First, it is necessary that the quality of the radiation be expressed in some uniform manner, such as equivalent voltage or half-value layer. As shown in Figure 1, such a procedure greatly simplifies the determination of the quantity (number of r) of the radiation which is necessary to produce the skin erythema along the various voltage ranges. To this is added the detailed description of the generating conditions, such as type of apparatus, coupling circuit, type of tube, target material, potential wave form and especially the type and thickness of the forefilter. Secondly, the quantity of the radiation administered must be expressed in r as measured on the patient's skin for the particular field employed. This permits the disregard of the changes incident to the variation of the size of fields. The corresponding value of r as measured in air, and the percentage of back-scattering for the size of field are also stated, for control. Third, the intensity factor is expressed in r/min. Here one may add the milliamperage value and the skin target distance to complete the description. The influence of the intensity factor on the erythema dose is as yet insufficiently explored. Fourth, the time factor, defined as the daily loss of radiation effect, assumes an ever-increasing importance, when the irradiation is fractionated and protracted over a certain length of time. In view of the fact that the various methods suggested for the consideration of this factor are lacking in accuracy and since there is as yet considerable discrepancy among them, it appears best to be content for the time being with a descriptive statement as, for example, of the magnitude of the fractions in r, measured on the skin and in air, of the interval between the fractions, of the total value of the fractions and of the total duration of the irradiation. Finally, one may include perhaps as a fifth factor the focal dose. This is expressed in percentage of the surface skin erythema dose by taking into consideration the depth dose incident to various voltage ranges and the number and size of fields used for the purpose of cross-firing.

It is not certain that the time is ripe for the standardization of all of these factors, especially as it concerns the intensity and time factors, but it is felt that the rapid progress which has been made during the last few years makes a beginning well justified. The initiative of the British X-ray and Radium Units Committee serves as a commendable example most worthy to be followed.

T. Leucutia

IN MEMORIAM

WITH profound sorrow The American Board of Radiology records the untimely passing of a distinguished fellow member, Doctor Willis F. Manges, November 24, 1936.

Renowned as physican and radiologist, Doctor Manges logically was appointed to the Board at its inception. As a member of this body he served the interests of his chosen specialty with extraordinary fidelity and efficiency. Outstanding among his traits were his deep sincerity, absolute fairness, unimpeachable integrity and remarkably sound judgment. Because he was wise, we looked to him for safe counsel; because he was eminently fair, we relied on him to make certain that no injustice was wrought by any act of ours; because he was steadfast, we counted confidently on his unfailing friendship. So long as we shall live his memory will abide with us, and through the years to come radiology and radiologists will reap the benefit of his unselfish work in their behalf.

It is ordered that this declaration be spread on the minutes, that it be published in the radiologic journals, and that the Secretary of the Board transmit a copy to Mrs. Manges with assurance of our heartfelt sympathy and respect.

A. C. Christie, *President*
B. R. Kirklin, *Secretary*

June 3, 1937.

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

United States of America

American Roentgen Ray Society
Secretary, Dr. E. P. Pendergrass, University Hospital, Philadelphia, Pa. Annual Meeting: Chicago, Ill., Sept. 13–17, 1937.

American College of Radiology
Secretary, Dr. E. L. Jenkinson, 1439 S. Michigan Ave., Chicago, Ill. Annual meeting: Chicago, Ill., September, 1937.

Section on Radiology, American Medical Association
Secretary, Dr. J. T. Murphy, 421 Michigan St., Toledo, Ohio. Annual meeting, 1938: To be announced.

Radiological Society of North America
Secretary, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y. Annual meeting: Chicago, Ill., Sept. 13–17, 1937.

Radiological Section, Baltimore City Medical Society
Secretary, Dr. Howard H. Ashbury, Baltimore. Meets third Tuesday each month, September to May.

Radiological Section, Connecticut State Medical Society
Secretary, Dr. Max Climan, 242 Trumbull St., Hartford, Conn. Meets twice annually in May and September. Special meetings may be called by the Chairman.

Radiological Section, Los Angeles County Medical Society
Secretary, E. N. Liljedahl, Los Angeles, Calif. Meets on the second Wednesday of each month at the County Society Building.

Radiological Section, Southern Medical Association
Secretary, Dr. Roy G. Giles, Temple, Texas.

Brooklyn Roentgen Ray Society
Secretary, Dr. E. Mendelson, 120 E. 19th St., Brooklyn, N. Y. Meets monthly on first Tuesday, October to April.

Buffalo Radiological Society
Secretary-Treasurer, Dr. Joseph S. Gian-Franceschi, 610 Niagara St., Buffalo, N. Y. Meets second Monday of each month except during summer months, place of meeting selected by the host.

Chicago Roentgen Society
Secretary, Dr. R. G. Willy, 1138 N. Leavitt. Meets second Thursday of each month October to May inclusive at the Palmer House.

Cincinnati Radiological Society
Secretary, Dr. H. G. Reineke, General Hospital Cincinnati, Ohio. Meets third Monday of each month, October to May, inclusive.

Cleveland Radiological Society
Secretary, Dr. North W. Shetter, 14600 Detroit Ave. Meetings are held at 6:30 P.M. at the Cleveland Chamber of Commerce Club rooms on the fourth Monday of each month from October to April, inclusive.

Denver Radiological Club
Secretary, Dr. N. B. Newcomer, 306 Republic Bldg., Denver, Colo.
Meets on the third Tuesday of each month.

Detroit Roentgen Ray and Radium Society
Secretary, Dr. E. R. Witwer, Harper Hospital. Meets monthly on first Thursday from October to May, at Wayne Country Medical Society Building.

Florida State Radiological Society
Secretary, Dr. Harold O. Brown, Tampa, Florida. Meetings held twice a year, May and November.

Illinois Radiological Society
Secretary, Dr. Cesare Gianturco, 602 W. University Ave., Urbana, Ill. Regular meetings held quarterly.

Indiana Roentgen Society
Secretary, Dr. C. C. Taylor, Indianapolis, Ind. Meeting held the second Sunday in May annually.

Long Island Radiological Society
Secretary, Dr. S. G. Schenck, 115 Eastern Parkway, Brooklyn, N. Y. Meets at Kings County Med. Soc. Bldg. on third Thursday of each month from October to May, at 8:30 P.M.

Michigan Association of Roentgenologists
Secretary, Dr. C. S. Davenport, St. Lawrence Hospital, Lansing, Mich. Three meetings a year, Fall, Winter, and Spring.

Milwaukee Roentgen Ray Society
Secretary, Dr. S. A. Morton, Columbia Hospital, Milwaukee, Wis. Meets monthly. Place of meeting named by the president.

Minnesota Radiological Society
Secretary, Dr. H. M. Weber, Mayo Clinic, Rochester, Minn.

Nebraska State Radiological Society
Secretary, Dr. D. A. Dowell, Medical Arts Bldg., Omaha, Nebr. Meets third Wednesday evening of each month.

New England Roentgen Ray Society
Secretary, Dr. E. C. Vogt, 300 Longwood Ave., Boston, Mass. Meets monthly on third Friday, Boston Medical Library.

Radiological Society of New Jersey
Secretary, Dr. P. S. Avery, New Brunswick, N. J. Meets annually at time and place of State Medical Society. Mid-year meetings at place designated by the president.

New York Roentgen Society
Secretary, Dr. R. W. Lewis, 140 E. 54th St., New York. Meets monthly on third Monday, New York Academy of Medicine, at 8:00 P.M.

North Carolina Roentgen Ray Society
Secretary, Dr. Major Fleming, Rocky Mount, N. C. Annual meeting at time and place of State Medical Society. Mid-year scientific meeting at place designated.

Central New York Roentgen Ray Society
Secretary, Dr. C. F. Potter, 820 S. Crouse Ave., Syracuse, N. Y. Three meetings a year—January, May, and November.

Pacific Roentgen Club
Secretary, Dr. L. H. Garland, 450 Sutter St., San Francisco, Calif. Meets annually, during meeting of California Medical Association.

Pennsylvania Radiological Society
Secretary, Dr. L. E. Wurster, Williamsport, Pa.

Philadelphia Roentgen Ray Society
Secretary, Dr. B. R. Young, Temple University Hospital. Meeting first Thursday of each month from October to May inclusive, at 8:15 P.M., in Thompson Hall, College of Physicians, 19 S. 22d St.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. Camp C. Thomas, 476 Lake Ave. Meets on second Thursday from October to May, inclusive, 8 P.M., Rochester Academy of Medicine Building.

St. Louis Roentgen Ray Society
Secretary, Dr. P. C. Schnoebelen, Missouri Bldg., St. Louis, Mo. Meets first week of each month. Time and place of meetings designated by president.

South Carolina X-Ray Society
Secretary, Dr. R. B. Taft, 105 Rutledge Ave., Charleston. Meets at time and place of South Carolina State Medical Association.

Tennessee Radiological Society
Secretary, Dr. F. B. Bogart, 311 Medical Arts Bldg.

* Secretaries of Societies not here listed are requested to send the necessary information to the Editor.

Chattanooga, Tenn. Meets annually at the time and place of the Tennessee State Medical Association.

TEXAS RADIOLOGICAL SOCIETY
Secretary, Dr. M. H. Glover, 414 Hamilton Bldg., Wichita Falls, Texas. Meets twice a year.

UNIVERSITY OF MICHIGAN DEPARTMENT OF ROENTGENOLOGY STAFF MEETING
Secretary, Dr. C. B. Peirce, University Hospital, Ann Arbor, Mich. Meets each Monday evening from September to June, at 7 P.M. at University Hospital.

UNIVERSITY OF WISCONSIN RADIOLOGICAL CONFERENCE
Secretary, Dr. F. A. Pohle, 1300 University Ave., Madison, Wis. Meets every Thursday from 4:00–5:00 P.M., Room 301, Service Memorial Institute.

VIRGINIA ROENTGEN RAY CLUB
Secretary, Dr. V. W. Archer, University Hospital, University, Va.
Meets annually in October.

CUBA

SOCIEDAD CUBANA DE RADIOLOGIA Y FISIOTERAPIA
Secretary, Dr. Francisco Padron, Enrique, Villuendas 64, Havana, Cuba. Meets monthly in Havana.

BRITISH EMPIRE

BRITISH INSTITUTE OF RADIOLOGY INCORPORATED WITH THE RÖNTGEN SOCIETY
Meets on the third Thursday of each month, from November to June inclusive, at 8:15 P.M., at 32 Welbeck St., London, W. 1, or as advertised.

SECTION OF RADIOLOGY OF THE ROYAL SOCIETY OF MEDICINE (CONFINED TO MEDICAL MEMBERS)
Meets on the third Friday of each month during the winter at 8:15 P.M. at the Royal Society of Medicine, 1, Wimpole St., London, W. 1.

SECTION OF RADIOLOGY AND MEDICAL ELECTRICITY, AUSTRALASIAN MEDICAL CONGRESS
Secretary, Dr. H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

RADIOLOGICAL SECTION OF THE VICTORIAN BRANCH OF THE BRITISH MEDICAL ASSOCIATION
Secretary, Dr. Keith Hallam, St. George's Hospital, K.E.W., Melbourne, E. 4, Victoria, Australia. Meets monthly from March to Nov. incl. for scientific discussions.

SECTION ON RADIOLOGY, CANADIAN MEDICAL ASSOCIATION
Secretary, Dr. A. C. Singleton, Medical Arts Bldg., Toronto 5, Ontario.

RADIOLOGICAL SECTION, NEW ZEALAND BRITISH MEDICAL ASSOCIATION
Secretary, Dr. P. C. Fenwick, The Hospital, Christchurch. Meets annually.

CONTINENTAL EUROPE

BELGIAN SOCIETY OF ROENTGENOLOGY
Secretary, Dr. J. Boine, Avenue des Alliés, 134, Louvain (Belgium).
Meets monthly on second Sunday at d'Egmonds Palace, Brussels, except in the summertime.

SOCIEDAD ESPAÑOLA DE RADIOLOGIA Y ELECTROLOGIA
Secretary, Dr. J. Martin-Crespo, Fuencarral, 7, Madrid, Spain. Meets monthly in Madrid.

SOCIÉTÉ DE RADIOLOGIE MÉDICALE DE FRANCE
Meets monthly on second Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

SOCIÉTÉ SUISSE DE RADIOLOGIE (SCHWEIZERISCHE RÖNTGEN-GESELLSCHAFT)
Secretary for French language, Dr. A. Grosjean, La Chaux de Fonds.
Secretary for German language, Dr. Scheurer, Molzgasse, Biel.
Meets annually in different cities.

SOCIÉTÉ FRANCAISE D'ELECTROTHÉRAPIE ET DE RADIOLOGIE MÉDICALE
Meets monthly on fourth Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

ASSOCIATION OF GERMAN ROENTGENOLOGISTS AND RADIOLOGISTS IN CZECHO-SLOVAKIA
Secretary, Dr. Walter Altschul, German University, Prague, II.52.

DEUTSCHE RÖNTGEN-GESELLSCHAFT (GESELLSCHAFT FÜR RÖNTGENKUNDE UND STRAHLENFORSCHUNG)
Meets annually in April, alternating one year in Berlin, one year in some other German city. Meets in addition every two years with the Gesellschaft deutscher Naturforscher und Aerzte.
Permanent secretary, Professor Dr. Haenisch, Klopstockstrasse 10, Hamburg, Germany.

SÜD- UND WESTDEUTSCHE RÖNTGENGESELLSCHAFT
Meets annually in different cities.

NORD- UND OSTDEUTSCHE RÖNTGENGESELLSCHAFT
Meets annually in different cities.

DUTCH SOCIETY OF ELECTROLOGY AND ROENTGENOLOGY
Holds two meetings a year in Amsterdam, one in the Spring, and one in the Fall.

SOCIETA ITALIANA RADIOLOGIA MEDICA
Secretary, Professor M. Ponzio, University of Turin, Turin.

SOCIETATEA ROMANA DE RADIOLOGIE SI ELECTROLOGIE
Secretary, Dr. Oscar Meller, Str. Banul Mărăcine, 30, S. I., Bucuresti, Roumania.
Meets second Monday in every month with the exception of July and August.

ALL-RUSSIAN ROENTGEN RAY ASSOCIATION, LENINGRAD, USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson, Meets annually.

LENINGRAD ROENTGEN RAY SOCIETY
Secretaries, Drs. S. G. Simonson and G. A. Gusterin.
Meets monthly, first Monday at 8 o'clock State Institute of Roentgenology and Radiology, Leningrad.

MOSCOW ROENTGEN RAY SOCIETY
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky.
Meets monthly on the first Monday at 8 o'clock, the place of meeting being selected by the Society.

POLISH SOCIETY OF RADIOLOGY
Secretary, Dr. Jan. Kochanowski, 45 Gornoslazka St., Warsaw. Meets annually.

WARSAW SECTION, POLISH SOCIETY OF RADIOLOGY
Secretary, Dr. B. Krynski, 11 Zielna St.
Meets once a month except in the summertime.

SCANDINAVIAN ROENTGEN SOCIETIES
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association. Each of the following societies, with exception of the Denmark Society, meets every second month except in the summertime.

SOCIETY OF MEDICAL RADIOLOGY IN SWEDEN
Meets in Stockholm.

SOCIETY OF MEDICAL RADIOLOGY IN NORWAY
Meets in Oslo.

SOCIETY OF MEDICAL RADIOLOGY IN DENMARK
Secretary, Dr. G. Biering, Copenhagen.
Meets on the second Wednesday of each month from October to July in Copenhagen, at 8 o'clock in the State Institute of Roentgenology.

SOCIETY OF MEDICAL RADIOLOGY IN FINLAND
Meets in Helsingfors.

VIENNA ROENTGEN SOCIETY
Meets first Wednesday of each month, at 6.30 P.M. at Zentral-Röntgen Institut des allgemeinen Krankenhauses Alserstrasse 4.

ORIENT

JAPAN X-RAY ASSOCIATION
c/o Orthopedic Surgery, Tokyo Imperial University.
Meets annually in April.

KINKI ROENTGEN-ABEND SOCIETY
Director, Dr. Prof. Taiga Saito, Ogawaoike Tyoto Japan. Meets bi-monthly on third Sunday.

PROGRAM OF THE FIFTH INTERNATIONAL CONGRESS OF RADIOLOGY

September 13 to 17, 1937

The program of the Fifth International Congress of Radiology, to be held at the Palmer House, Chicago, Illinois, is now complete. It has been arranged under the following divisions:

I. Opening session on Monday evening, September 13, at which addresses will be delivered by Dr. William J. Mayo, Dr. Gösta Forssell, Dr. H. R. Schinz and Dr. A. C. Christie.

II. Four full sessions of the Congress occupying the entire forenoons from Tuesday to Friday inclusive. The following is a partial list of authors and subjects for these general sessions:

The Production of X-rays of Very Short Wave Length, Dr. William D. Coolidge, Schenectady, New York, U. S. A.

Ionization by High Voltage X-rays and Gamma Rays, Dr. Arthur H. Compton, Chicago, Illinois, U. S. A.

Cancer of the Larynx, Dr. Henri Coutard, Paris, France.

Racial Variations in the Incidence of Carcinoma, Dr. Max Cutler, Chicago, Illinois, U. S. A., and Sir George Lenthal Cheatle.

The Rôle of the Autonomous Movements of the Gastrointestinal Mucous Membrane in Digestion, Dr. Gösta Forssell, Stockholm, Sweden.

The Treatment of Hodgkin's Disease by Radiotherapy, Dr. René Gilbert, Geneva, Switzerland.

Main Lines in Technical or Biological Studies of Radiation Therapy Methods, Prof. Hans Holfelder, Frankfurt-am-Main, Germany.

Important Points in the Roentgen and Radium Therapy of Tumors, Prof. Hermann Holthusen, Hamburg, Germany.

The Development of High Voltage X-ray Tubes at the California Institute of Technology, Dr. Charles C. Lauritsen, Pasadena, California, U. S. A.

Production and Biological Effects of Neutrons, Dr. Ernest O. Lawrence, Berkeley, California, U. S. A.

The Radiological Evaluation of the Size and Form of the Heart, Prof. Gian Giuseppe Palmieri, Bologna, Italy.

The Use of the Roentgen Rays in the Diagnosis and Treatment of Tumors of the Bladder, Dr. George E. Pfahler, Philadelphia, Pennsylvania, U. S. A.

Physical and Biological Dosage, Prof. Mario Ponzio, Turin, Italy.

Movements of the Oesophagus, Stomach, Duodenum and Ileum as Revealed by Cineradiographic Films, Dr. Russell J. Reynolds, London, England.

Diagnosis, Pathology and Roentgen Treatment of Peritendinitis Calcarea, Dr. Carl Sandström, Stockholm, Sweden.

Cerebral Cystography and Cisternography, Prof. Arthur Schüller, Vienna, Austria.

Teleroentgentherapy, Dr. Felix Sluys, Brussels, Belgium.

Roentgen Kymography as a Diagnostic Help, Prof. Pleikart Stumpf, Munich, Germany.

The Production of Penetrating Radiations by Means of Electrostatic Generators, Dr. Robert G. Van de Graaff, Cambridge, Massachusetts, U. S. A.

Bronchial Carcinoma, A Roentgen-pathological Study, Dr. Nils Westermark, Stockholm, Sweden.

In addition to the above subjects, there will be reports from Austria, France, Germany, Great Britain, Italy and the United States on the present status of education and organization in radiology. During these sessions, there will also be reports by the Chairmen of the International Committee on Radiological Units and the International Committee on Protection. At a special afternoon session, Dr. Russell J. Reynolds of London and Dr. Maurice Van de Maele of Brussels will give reports and demonstrations of the indirect and direct methods of cinematography.

III. Three evening sessions of the Congress, namely on Tuesday, Wednesday and Thursday, are devoted to the three special annual lectures given under the auspices respectively of the American Radium Society, the American Roentgen Ray Society and the Radiological Society of North America. Dr. Douglas Quick of New York City will deliver the Janeway Lecture on "Carcinoma of the Larynx"; Dr. George

E. Pfahler of Philadelphia will deliver the Caldwell Lecture on "The Treatment of Carcinoma of the Breast"; and Dr. George W. Holmes of Boston, the Carman Lecture on "The Development of Post-Graduate Teaching in Radiology."

IV. Educational sessions which were announced in this Journal in the March and April numbers will be held from 8:00 to 9:00 A.M. on the mornings of Tuesday, Wednesday, Thursday and Friday, September 14 to 17, inclusive. These courses are open to all members of the Congress but members must register for the course which they desire to take. The courses are being filled very rapidly and anyone who wishes to take one of them should register at once.

The afternoon sessions of the Congress, Tuesday, September 14 to Friday, September 17 inclusive are organized in the following Sections.

Section IA—Roentgen Diagnosis
Chairman, Dr. James T. Case
Section IB—Roentgen Diagnosis
Chairman, Dr. Charles A. Waters
Section IC—Roentgen Diagnosis
Chairman, Dr. Fred M. Hodges
Section IIA—Radiotherapy
Chairman, Dr. Albert Soiland
Section IIB—Radiotherapy
Chairman, Dr. B. P. Widmann
Section IIC—Radiotherapy
Chairman, Dr. A. U. Desjardins
Section III—Radiophysics
Chairman, Dr. G. Failla
Section IV—Radiobiology
Chairman, Dr. Francis Carter Wood
Section V—Electrology and Light Therapy
Chairman, Dr. Norman E. Titus

It is impossible in this brief notice to list the papers which will be presented before the Sections. Leading workers from every country in the world will present papers on diagnosis, therapy, radiophysics, radiobiology and electrology on every important subject in the entire field of radiology. The time limit for presentation of papers will be adhered to strictly and the programs of the various Sections will be so synchronized that any member may arrange for himself a program which will include papers in all of the Sections.

During the month of August, all members of the Congress will receive a preliminary program listing all of the addresses and papers to be presented before the Congress, both in the general sessions and the Sections.

Applications for membership are being received in large numbers in the office of the General Secretary, indicating that there will be a large attendance at the Congress. Since the membership fee includes the right to register for one of the educational courses and attendance at all of the scientific and social events, including the final grand banquet on the closing night, it is important for everyone to complete his membership at the earliest possible moment.

FIFTH INTERNATIONAL CONGRESS OF RADIOLOGY

September 13–17, 1937

Membership in the Fifth International Congress of Radiology closed on August 14, 1937. Early closing dates for membership in conventions of this character constitute one of the disappointing features which cannot be avoided. Those who have forwarded their applications for membership since that date will understand that the officers and organizers of the Congress regret that it became necessary, but the Portrait Catalogue and other publications of the Congress must be completed and ready for distribution when registration is opened at 1 o'clock Sunday, September 12, 1937.

Attendance at the Congress is not limited to members of the Congress. By the payment of a small registration fee, one may be registered as a guest of the Congress and enjoy the full privileges of the scientific program and scientific exhibits throughout the period of the Congress.

Educational courses, which are free to members of the Congress, are open to

registered guests of the Congress upon the payment of an additional registration fee. The very nature of the educational courses naturally limits the numbers that may be accommodated, and registration for the courses will close accordingly. For further information concerning these courses, please refer to the March or April issue of this Journal, or write your inquiry to the Secretariat, 2561 North Clark Street, Chicago.

The Grand Banquet, which occurs on Friday evening, as the closing feature of the Congress, is free to all of the members and associate members.

Registered guests of the Congress will be required to purchase tickets at the registration desk if they wish to attend the Grand Banquet. They may also register associate members of the Congress by the payment of the regular associate membership fee.

It is exceedingly important that the guests as well as the associate members be registered as far ahead of the opening of the Congress as possible in order that the committees that are providing entertainment features may know the approximate number for which arrangements are to be made.

Contributions to the scientific program will be presented in the three official languages of the Congress. In addition to the language used by the essayist, the context of his address will be projected on a screen in the other two official languages of the Congress and they will be synchronized as far as possible with the address as it is delivered. It is obvious that this feature will add greatly to the success of this Congress, since a very great majority of the audience in the forenoon general sessions, and in the afternoon sectional meetings will be English speaking and understanding while the Contributors' presentations will be more equally divided among English, German and French.

It would appear that almost every radiologist will endeavor to attend this Congress. It is the first opportunity American radiologists have had to attend a Congress within our own country with contributors representing all of the leading countries of the world. Furthermore, it is the first time that a program for an international congress of radiology has been so arranged that all of the guests will be able to understand any contribution they choose to hear.

With approximately 300 contributions on the program, one may choose papers from any phase of radiology and learn of the most recent advances in that particular field.

To the Members of the American Roentgen Ray Society:

The Thirty-eighth Annual Meeting of the American Roentgen Ray Society will be held at the Palmer House in Chicago, Illinois, in conjunction with the Fifth International Congress of Radiology, September 13–17, inclusive, 1937.

The Executive Council will hold its annual meeting at 12:15 P.M., Sunday, September 12. Any communications or matters which the members of the Society wish to present to the Council should be in the hands of the Chairman, Dr. Carleton B. Peirce, University Hospital, Ann Arbor, Michigan, not later than August 30.

Because of the full scientific program of the International Congress, the Annual Business Session of the Society will convene at 3:30 P.M., Monday, September 13 for the installation of the President-Elect, the reports of officers and committees, the report of the Executive Council and the election of new members, with such other business as may properly come before the Society. A full attendance of the membership is desired.

On Wednesday, September 15, the officers and invited foreign members of the International Congress of Radiology will be the guests of the Society at dinner in the Red Lacquer Room of the Palmer House at 6:30 P.M. The retiring President, Dr. C. A. Waters, will present the medals awarded for the scientific exhibits at the Cleveland meeting. Excellent entertainment and a good menu have been arranged. Members of the Society may purchase

tickets for this dinner for themselves and guests at the actual cost of the dinner. Reservations should be made through Dr. Kirklin's office.

The President of the Fifth International Congress of Radiology has very graciously invited the American Roentgen Ray Society to arrange the program for and to conduct the third general evening session of the Congress, which will follow the dinner. The annual Caldwell Lecture will be given at this time by Dr. George E. Pfahler.

The second Business Session of the Society will convene at luncheon, 12:15 P.M., Thursday, September 16, for the election of officers and members of standing committees, unfinished or new business and the appointment of special committees by the President. Tickets for the luncheon may be purchased at the registration desk.

Charles A. Waters, *President*
B. R. Kirklin, *President-Elect*
Eugene P. Pendergrass, *Secretary*
Carleton B. Peirce, *Chairman of the Executive Council*

Tuesday Evening
September 15, 1937
American Roentgen Ray Society Night

6:30 P.M. Red Lacquer Room.

Dinner for American Roentgen Ray Society members, Officers of the Fifth International Congress of Radiology and invited guests.

9:00 P.M. Grand Ball Room.

President's Address

"Responsibilities of the Radiologist." B. R. Kirklin, M. D., Rochester, Minnesota

The Caldwell Lecture

"Treatment of Carcinoma of the Breast." George E. Pfahler, M. D., Philadelphia, Pennsylvania

Presentation of Medal to Dr. Pfahler. W. Edward Chamberlain, M. D., Philadelphia, Pennsylvania

REPORT OF THE STANDARDIZATION COMMITTEE OF THE AMERICAN RADIUM SOCIETY*

ON THE METHODS USED AND RESULTS OBTAINED BY MEMBERS OF THE SOCIETY IN RADIOTHERAPY OF CANCER OF THE UTERINE CERVIX*

In order to ascertain the views held by members of the American Radium Society on the principles of treatment in cancer of the uterine cervix and the results attained thereby, the Standardization Committe sent out a questionnaire. Though only a little more than a fifth of the membership of the Society answered in detail, this permitted nevertheless some insight into results and methods of treatment of this disease in this country.

The material contained in the questionnaire may be roughly divided into two parts: the statistics of results, and the technical details of treatment. In this connection there should be mentioned the criteria for correct reporting of results of radiotherapy in cancer of the uterine cervix which were recently postulated by the Health Organization of the League of Nations. They have been made available to the American Radium Society through the kind efforts of the editor, Dr. James Heyman of Stockholm:

Statistics should consist only of cases actually examined and treated at the clinic from which they are reported. The total number of patients seen should be stated, and all cases classified into groups according to the clinical extent of the disease at the time when treatment is begun. Percentage calculations of results may be accepted only when the number of cases is not less than one hundred. For similar calculations based on groups of 16 to 99 cases, a correction factor should be applied, and percentage reporting should be avoided where only 15 or less cases are available. The statistics should consist only of cases of cancer of the cervix uteri (including cancer of the stump)

* Presented at the Twenty-second Annual Meeting, American Radium Society, Atlantic City, N. J., June 7–8, 1937.

which are primarily treated by radium and roentgen rays, and where the first treatment was given five years prior to the report.

The following clinical types of cases should be excluded: cancer of the corpus uteri and vagina, recurrence after radical operation, patients radiologically treated elsewhere, and patients primarily admitted for combined operative and radiologic treatment. The following histologic types of cases should be excluded: precancerous conditions, chorio-epithelioma, sarcoma, and malignant mixed tumors.

The stage of the cancer of the cervix uteri should be defined as follows:*

Stage I: The growth is strictly limited to the cervix uteri. Uterus mobile.

Stage II: Lesion spreading into one or more fornices with or without infiltration of the parametrium adjacent to the uterus, the uterus retaining some degree of mobility.

Stage III: (a) Nodular infiltration of the parametria on one or both sides extending to the wall of the pelvis, with limited mobility of the uterus or massive infiltration of one parametrium with fixation of the uterus.
(b) More or less superficial infiltration of a large part of the vagina, with a mobile uterus.
(c) Isolated metastases in the pelvic glands, with a relatively small primary growth.
(d) Isolated metastases in the lower part of the vagina.

Generally speaking, all cases not falling into Stages II and IV will be placed under Stage III.

Stage IV: (a) Cases with massive infiltration of both parametria extending to the walls of the pelvis.
(b) Carcinoma involving the bladder or rectum.
(c) The whole vagina infiltrated (rigid vaginal passage) or one vaginal wall infiltrated along its whole length with fixation of the primary growth.
(d) Remote metastases.

The Standardization Committee feels that acceptance by the American Radium Society of the above criteria will contribute to international cooperation in the effort to improve the treatment of this disease. The Committee recommends the adoption of these standards, with the addition that only microscopically proved cases be accepted.

In attempting to gather information as outlined in the questionnaire, the League of Nations definitions for Groups I and II were adopted practically verbatim. The third group mentioned in the questionnaire corresponds roughly to Stage III. Stage IV of the League of Nations classification was not included, as it was felt that five-year arrests in this group would be so rare as to be negligible from the standpoint of new statistical information. In retrospect, it might have been preferable, for the sake of uniformity, to follow strictly the League of Nations nomenclature, and we recommend this for the future.

STATISTICS

Fifteen of the 31 reports contained statements of five-year results. Several of the larger clinics rendered them in the form of reprints, so that there were available records of 2,855 radiologically treated cases of cancer of the cervix. Three hundred and eighty-five of these belong in the first group, with a 37 per cent five-year freedom from clinical evidence of cancer. It is interesting to note that composite results for Group I cases from the larger American and foreign clinics gathered by Schreiner[1] vary between 42 per cent and 80 per cent.

* At the last executive session of the American Radium Society, Dr. Henry Schmitz suggested the following change which was accepted by the members present:

Stage I remains unchanged.

Stage II should be defined as "Lesion spreading into one or more fornices, the uterus retaining some degree of mobility."

Stage III should be defined as "(a) Nodular infiltration of the parametria on one or both sides extending to the wall of the pelvis, with limited mobility of the uterus." "(b) Isolated metastases in the pelvic glands, with a relatively small primary growth." Generally speaking, all cases not falling into Stages II and IV will be placed under Stage III.

Stage IV: (a) Cases with massive infiltration of both parametria extending to the walls of the pelvis with fixation.

(b) Carcinoma involving the bladder or rectum.

(c) 1. More or less superficial infiltration of a large part of the vagina, with a mobile uterus.

2. Isolated metastases in the lower part of the vagina.

3. The whole vagina infiltrated (rigid vaginal passage) or one vaginal wall infiltrated along its whole length with fixation of the primary growth.

(d) Remote metastases.

In Group II, members reported 738 cases, with 18 per cent five-year clinical arrests; whereas Schreiner's corresponding figure is 33.5 per cent. In Group III there were reported 1,732 cases, with 16.6 per cent five-year arrests. This compares favorably with Schreiner's composite figures, and the record of only 7 per cent five-year clinical arrests in 126 Group III cases treated at the Curie Institute by intracavitary radium therapy alone. It falls considerably short of the report of 34.5 per cent five-year arrests in 174 similar cases treated at the Curie Institute with the addition to the intracavitary radium of external radium element pack or roentgen therapy.[2] Of the 186 stump cases reported by members of our Society, 15 per cent were clinically arrested for five years, which compares favorably with other similar statistics.[1,2]

ROENTGEN THERAPY

It is quite evident that the addition of external irradiation in cases belonging to Groups II and III is important. Of the 31 members who replied, 26 stated that they routinely add external roentgen therapy to the intracavitary radium therapy; 15 use a single series, and 11 repeat the series at varying intervals. Practically all use 200 kv., the majority employing between 15 and 30 ma.[3] Half of the authors employ 50 cm. S.T.D., the other half 60–80 cm. Twenty-one prefer a filter of 1 mm. of copper or more; 5 still use 0.5 mm. of copper. The portals are usually two anterior and two posterior pelvic, or two anterior, two posterior and two lateral. Their size varies between 8×12 cm. and 15×15 cm. Dosage per field is 1,200–2,000 r/o with a combined dose for all pelvic portals of 4,800–12,000 r/o. Only 4 authors still prefer using one anterior and one posterior, 20×20 cm. field, their dose per field averaging less than 1,750 r/o, or a total per pelvis of only 3,500 r/o or less. While the group using multiple fields give 200–400 r per day, and usually employ twenty to forty days for the treatment, those using larger fields give more per day but treat for only four to ten days. Practically all give only one treatment a day, though they may treat one or two fields.

RADIUM THERAPY

Twenty-two members state that they use continuous irradiation with radium; 9 interrupt the treatment. Half separate the uterine and vaginal radium applications, and half give them simultaneously. A little less than half of the authors use, for the entire radium treatment, thirty hours or less; a similar number use 100 hours or more. The significance of the duration of treatment will be discussed later. It is believed that it is of great importance, especially in its bearing on the occurrence of complications in the surrounding normal tissues.

Twenty-five of the 31 authors divide their radium dosage so that the larger part is given in the uterus and the smaller part in the vagina. Thus about half use 3,500–5,000 mg-hr. in the uterus and 3,000 mg-hr or more in the vagina, making a total of 6,500 and rarely up to 10,000 mg-hr. for the combined intrauterine and vaginal radium dosage. In only 5 instances is a combined routine dosage of less than 6,000 mg-hr. reported. The type of uterine applicator is usually a malleable or rigid container in which two or more radium tubes are placed in tandem. The vaginal applicators are usually metal tubes, cork cylinders, molds, or flat boxes which contain the radium tubes. Three authors, however, still use seeds in the cervix, and 3 others the intravaginal bomb.

Filters of 0.5–1.0 mm. of gold or platinum for uterine applicators are employed by 23; while 4 still employ 2 mm. of brass, three 0.5 mm. of silver, and one 0.5 mm.

[1] Schreiner, B. F. Five and ten year end-results of treatment of cancer of the cervix uteri by irradiation. *Surg., Gynec. & Obst.*, 1936, *62*, 764–768.

[2] Regaud, C. Quelque problèmes relatifs au traitement radiothérapique des épithéliomas cervico-utérins. *Cancer, Bruxelles*, 1935, *12*, 93–112.

[3] There is a change in policy at the Curie Institute, and higher milliamperage is recommended by F. Baclesse in his "Quelques considérations sur la roentgenthérapie employée seule dans le traitement des épithéliomas avancés du col de l'utérus et du vagin." *Radiophys. et radiothérapie*, March, 1937.

of lead. Nearly all authors keep the applicators in place by packing, though 2 authors suture the uterine tube in place.

COMPLICATIONS

Only 11 of the 31 do not report any difficulties or complications after the treatment, though some post-irradiation atrophy of the vagina was noticed by most. Vesical or rectal fistulae were noted by seven. Absorption of areas invaded by cancer seemed to account for this complication in most cases, so that to a degree this was unavoidable. Ten reported pyometra. Seven of these employed thirty to forty hours to give the intrauterine radium. Seven reported proctitis; 6 of these used between thirty and forty hours, and the seventh concentrated all of his intrauterine radium treatment in one 2 cm., 25–50 mg. tube which he moved into various positions in the uterus, a method in which misplacement of the tube is very likely. Finally, of the 8 who reported the occurrence of intestinal obstruction, 7 used between thirty and forty hours for their intrauterine radium while the eighth stated that he felt that the cases of intestinal obstruction occurred "due to over-irradiation because of malposition of the radium."

SUMMARY

Fifteen of the 31 members who replied reported their results in 2,855 radiologically treated cases of cancer of the uterine cervix. Their five-year clinical arrests were 37 per cent for Group I, 18 per cent for Group II, and 16.6 for Group III, with 15 per cent for stump cases. Twenty-six of the 31 routinely add external roentgen therapy to the intracavitary radium, most employing 15 or more milliamperes, a filter of 1 or more millimeter of copper, 4 or 6 pelvic fields varying in size from 8×12 cm. to 15×15 cm. One treatment is administered daily for twenty to forty days, the latter being favored by some more recently; 200–300 r in air divided over one or several fields are generally given daily, with a total dose of 1,200–2,000 r per field, or 4,800–12,000 r per pelvis, 7,000–8,000 r being recommended by a number of members as the average.

As far as the radium technique is concerned, the majority of the replies state that the authors routinely use about 6,500–7,500 mg-hr. filtered through 1 mm. of gold or platinum, a little more than half of the dose being given in some form of intrauterine applicator and the rest divided in two or more vaginal applicators. Seeds and intravaginal bomb are rarely used.

A little less than half of the answers still favor a period of thirty hours or less for the combined intrauterine and intravaginal application of radium. A similar number use 100 hours or more for the same purpose. The importance of external irradiation in all but cancers limited to the cervix has been stressed. It was not fully realized, however, how much the addition of this irradiation increases the damage to the intestines which is normally produced by the intracavitary radium. When either the internal or external irradiation is given in a short period of time without reducing the total quantity, this effect is increased still further and marked intestinal damage may occur. Practically all cases of pyometra, cystitis, proctitis and intestinal obstruction were reported by authors using the shorter period of treatment. It would therefore seem that it is definitely preferable to extend the period of radium treatment for longer than 100 hours.

The Standardization Committee regrets its inability to present a more complete summary of the results and methods of radiotherapy in cancer of the uterine cervix by the membership of the American Radium Society. Because of this, definite conclusions or recommendations are not made, except to urge the adoption of the standards of the Health Organization of the League of Nations.

The report serves to stress the well-known fact that radium and roentgen therapy of cancer of the uterine cervix should be carried out only by physicians who are familiar with the clinical aspect of

the disease, have had experience in the use of these physical agents, and know their indications, limitations and dangers. The best method of treatment and the dosage depend on careful clinical judgment, and may vary from case to case. In this connection we wish especially to call attention to, and to condemn, the promiscuous sale of radium or radon by commercial companies to all comers, and the long-distance prescription of radiation dosage by medical advisers who do not see the patient personally and therefore cannot evaluate all the factors which enter into correct treatment.

MAURICE LENZ, *Chairman*
WILHELM STENSTROM
L. R. SANTE

INDIANA ROENTGEN SOCIETY

The annual meeting of the Indiana Roentgen Society was held in Indianapolis on May 9, 1937. Dr. J. N. Collins, Indianapolis, was installed as President. Other officers elected for the coming year were: Dr. Stanley Clark, South Bend, President-Elect, Dr. Juan Rodriguez, Fort Wayne, Vice-President, and Dr. Clifford C. Taylor, Indianapolis, Secretary-Treasurer.

Dr. J. C. Bell of Louisville, Kentucky, was a guest for the day and after dinner he addressed the society, his subject being "The Less Common Diseases of the Colon, including Amebiasis."

CINCINNATI RADIOLOGICAL SOCIETY

The May meeting of the Cincinnati Radiological Society had as its guest Dr. M. A. Loebell of Zanesville, Ohio, who gave an interesting address on his experimental therapy tube. Dr. George Benzeng of St. Elizabeth's Hospital, Covington, Kentucky, was elected President, and Dr. Justin E. McCarthy of Cincinnati, Ohio, was elected Secretary-Treasurer of the Radiological Society of the Academy of Medicine, Cincinnati. Meetings are held on the third Tuesday of each month.

CONNECTICUT STATE MEDICAL SOCIETY

SECTION ON RADIOLOGY

The Connecticut State Medical Society held its One Hundred and Forty-fifth Annual Meeting at Bridgeport on May 19 and 20, 1937. In the Section on Radiology Dr. George Levene of Boston presented a paper on "The Value of Roentgenologic Study in the Diagnosis of Heart Disease." At the business meeting following the program the officers elected for the coming year were: Chairman, Kenneth K. Kinney, M.D., Willimantic, Connecticut; Vice-Chairman, Francis M. Dunn, M.D., New London, Connecticut; Secretary-Treasurer, Max Climan, M.D., Hartford, Connecticut.

ADVISORY BOARD FOR MEDICAL SPECIALITIES

The annual meeting of the Advisory Board for Medical Specialties, which is the coördinating Board of the twelve certifying boards in the various specialties, the Association of Medical Colleges, the American Hospital Association, the Federation of State Medical Boards of the U.S.A., and the National Board of Medical Examiners was held at Atlantic City, N. J., on June 6, 1937.

The following officers were selected:

Officers and Executive Committee

Willard C. Rappleye, M.D., President, New York City.
W. P. Wherry, M.D., Vice-President, Omaha, Nebraska.
Paul Titus, M.D., Secretary-Treasurer, Pittsburgh, Pennsylvania.
W. B. Lancaster, M.D., Boston, Massachusetts.
R. C. Buerki, M.D., Madison, Wisconsin.

Dr. Louis B. Wilson, of Rochester, Minnesota, the retiring president of the Board, was elected an emeritus member of the Board.

PAUL TITUS, *Secretary*

INDEX TO ABSTRACTS

ROENTGEN AND RADIUM THERAPY

Juul, J.: The protracted fractional roentgen treatment of malignant tumors ad modum Coutard 381

Schwarz, G., and Frank A.: The quality of the rays and the skin reaction 382

Miescher, G.: Results of carcinoma treatment at the Dermatological Clinic of Zürich 382

Hintze, A.: Stubborn carcinomata of the skin and their treatment 382

Dieterich, W., and Edinger, A.: Results of radiotherapy of cancer of the uterus from 1926 to 1931 383

Hamann, A., Göbel, A., and Engelmann, K.: The radiotherapy of cancer of the uterus in the St. George General Hospital in Hamburg from June, 1929, to December, 1931 383

Gál, F.: Recurrences of cancer of the uterus .. 385

Voltz, F.: Further results of radiotherapy of carcinoma of the uterus 385

Von Büben, I.: Results of radiotherapy of inoperable carcinoma of the cervix 386

Bolaffio, M.: Selective treatment of carcinoma of the cervix 386

Kirchhoff, H., and Drenckhahn, J.: Primary morbidity and mortality of intensive treatment of carcinoma of the cervix . 387

Dietel, F. G.: What has radiotherapy accomplished so far in inoperable carcinoma of the cervix? 387

ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN AND RADIUM THERAPY

Juul, Jens. The protracted fractional roentgen treatment of malignant tumors ad modum Coutard. *Acta radiol.*, 1936, *17*, 209–234.

During the period from 1931 to 1934 the author used protracted fractional roentgen treatment in 121 cases of malignant epithelial tumors of the upper air passages. Among these 38, or 31 per cent, are still free of symptoms after periods varying from one to five years. The absolute yield after one year is 31 per cent, after two years 31 per cent, after three years 25 per cent and after four years 27 per cent. Details are given of the distribution according to localization, sex, metastases and histological findings.

During the same period 106 cases of malignant epithelial tumors of the mouth were treated. Of these patients 33 are apparently well after periods varying from one to five years. Protracted fractional roentgen treatment was used in 73 of these cases; among these 8 are free of symptoms as a result of the roentgen treatment alone, while in 10 supplementary treatment with radium or electrosurgery was necessary.

Among other forms of cancer in which protracted fractional roentgen treatment may be used to advantage are carcinoma of the skin, extensive carcinomas of the lips, eyelids and external ear in which radium is hard to apply, carcinoma of the vulva, the penis, the superior maxilla and in inoperable carcinomas of the breast and recurrences following operation for carcinoma of the breast.

The technique is adapted to each individual case but as a general rule he tries to extend the treatment over a rather long period and keep the reaction moderate in degree. The rays used are the hardest their apparatus is capable of producing—165–180 kv. with copper-tin filter and a half-value layer of about 1.5 mm. copper, the object being to obtain the greatest penetration possible. Daily observation and strict adaptation to the reactions found is an absolute essential of the treatment.

In favorable cases the tumor begins to disappear after a few days' treatment and any ulcerations become covered with a thin, fibrous

yellowish membrane, epithelitis of the tumor. Epithelitis on the ulcerations seems to occur in all cases in which the tumor eventually disappears entirely. Epithelitis on the surrounding mucosa is often associated with good results, but complete disappearance of the tumor may be brought about without epithelitis on the surrounding mucosa and the tumor does not always disappear even if there is a confluent epithelitis on the mucous membrane.

The comparative value of protracted fractional roentgen irradiation and radium irradiation is discussed, and the author believes that so far no facts have been brought forward that prove the superiority of radium.—*Audrey G. Morgan.*

SCHWARZ, G., and FRANK, A. Strahlenqualität und Hautreaktion. (The quality of the rays and the skin reaction.) *Strahlentherapie*, 1934, *50*, 145–156.

The author describes tests on human subjects which showed that with qualities of rays from 178 kv., filter 0.5 mm. copper and 1 mm. aluminum to 110 kv., 1 mm. aluminum (λ-average 0.16 Å to λ-average 0.33 Å) measured ionometrically doses of equal size (1,600 r) with the same rate, 40 r per minute, show a distinctly greater degree of dermatitis when harder radiation is used. This contradicts the opinion still widely held that the softer (more absorbable) roentgen rays are, the more they injure the skin.—*Audrey G. Morgan.*

MIESCHER, G. Erfolge der Karzinombehandlung an der Dermatologischen Klinik Zürich. (Results of carcinoma treatment at the Dermatological Clinic of Zürich.) *Strahlentherapie*, 1934, *49*, 65–81.

The author discusses the treatment of skin carcinomata at the Zürich Dermatological Clinic by the method of a single large dose and by Coutard's prolonged fractional method. With the single dose intensive method, 1,200 to 1,600 r was given at a single sitting with soft rays (0.5 to 1 mm. aluminum filter) for superficial cancers and somewhat harder ones (0.1–2 mm. copper) for deeper ones. The time varied from one-half to one hour and the intensity from 20 to 60 r per minute. The size of the fields in most cases was less than 5 cm. in diameter. Experience has shown that larger fields do not bear these doses so well.

In the fractional method individual doses of 200 to 220 r were given up to a total of 3,800 to 4,600 r. The time varied from twenty to sixty minutes, the intensity from 2.6 to 12 r per minute. As in the intensive method the hardness of the rays was adapted to the depth of the tumors. In some cases in which the cancers were relatively small, two doses a week of 400–440 r were given, up to a total of 7 to 9 doses, or 2,400 to 3,200 r.

The carcinomata were divided into basal cell, terebrant basal cell, small prickle cell, large prickle cell and Bowen's disease. Tables are given showing the details of the treatment and results according to method of treatment and localization of the cancers.

They show that in basal cell and small prickle cell carcinomata (diameter of the tumor up to 2 cm.), the single intensive irradiation method gives excellent results—cure in 94 to 96.5 per cent of the cases. The results were as good in carcinoma of the lip as in carcinoma of the skin. In large prickle cell carcinomata the results were not nearly so good. Removing tumor masses by electrocoagulation before irradiation improved the results at the primary focus but it is questionable whether the incomplete destruction of the tumor did not contribute to gland metastases.

In large basal cell carcinomata the fractional method gave excellent results but only a third of those of the terebrant form were cured, some of these after preliminary treatment with electrocoagulation. But this is an improvement over former methods. In extensive prickle cell carcinomata the advance made with the Coutard method is not so striking. A large number of the cases were not cured even locally; therefore this cannot be considered the method of choice and in each case careful consideration should be given the question of whether other radiological methods or electrocoagulation might not be of greater service. The method of two weekly irradiations gave very good results and should be tested further.—*Audrey G. Morgan.*

HINTZE, ARTHUR. Hartnackige Hautkarzinome und ihre Heilung. (Stubborn carcinomata of the skin and their treatment.) *Strahlentherapie*, 1934, *51*, 237–270.

The author describes 71 cases of stubborn carcinomata of the skin and illustrates them with photographs. In 39 of the cases operation was the primary treatment, the primary operation being performed by the author in 9 of the cases. In 32 the primary treatment was irradia-

tion, 15 of them being irradiated by the author. Sixty-two of the cases were carcinoma of the face; 16 of these were multiple; 4 were on the trunk or extremities, 3 were lupus carcinoma and one a roentgen carcinoma. Of the 4 cases treated by operation alone none were cured. Of the 35 that were operated on first but afterward treated by irradiation, 19 were cured. Of the 17 given primary irradiation elsewhere 1 was cured by later operation; 4 were cured at the author's hospital by irradiation. Among the 15 to whom he gave primary irradiation, in 9 multiplicity was the cause of the stubborn persistence of the disease; in 6 cases it was due to persistence or recurrence of the primary tumor. Among the group of multiple tumors 8 are now cured, among the recurrent group 3 are cured. Among the 3 cases of recurrence that were not cured two were treated with the old technique of small doses given frequently, one with moderately large doses, none with very large doses.

Stubborn persistence of skin carcinomata if not due to multiplicity is caused by insufficient treatment in the beginning.—*Audrey G. Morgan.*

Dieterich, W., and Edinger, A. Ergebnisse der Strahlenbehandlung des Gebärmutterkrebses von 1926–1931. (Results of radiotherapy of cancer of the uterus from 1926 to 1931.) *Strahlentherapie*, 1934, *50*, 557–565.

The authors report the results of their treatment in the Municipal Hospital of Mannheim. It is a hospital of moderate size but they think their results perhaps worth reporting for purposes of comparison with larger statistics.

Among the total of 237 cases treated 89 were living and well on April 1, 1934; this is 37.5 per cent of the total. Among these 124 were inoperable cases; 23 of these, or 18.5 per cent, are living. Among the 48 cases treated with roentgen rays alone 8 are living, or 16 per cent, among the 20 treated with roentgen rays alone 4 are living, or 20 per cent, and among the 56 treated with combined treatment 11 are living, or 19.6 per cent. Among the operable cases 59.3 per cent are living. Tables are given showing the details of the results with reference to age, length of life of the patients who died and the results in the small number of cases of the body of the uterus and the ovary.

Their results are about the same as those reported by other authors. Inoperable cases, and unfortunately they are the majority, should be given combined treatment with radium and roentgen rays. The associated roentgen treatment cures glandular metastases or stimulates the defensive forces of the tissues.

Their radium is enclosed in tubes containing 10 mg. each; the container has a wall 0.2 mm. thick and the filter is 1.0 to 1.5 mm. brass. The patients are given about 5,000 to 6,000 mg-hr., about half of it intracervically. Whether this is given at one treatment or distributed over two months depends on the reaction in the individual case. For the roentgen therapy they used 180 kv., 0.9 mm. copper half-value layer; 3–4 ma.; 0.5 mm. copper filter; 40 cm. distance; fields 10×15 cm. or 20×20 cm. Not more than 60 per cent S.E.D. was given at one treatment, an S.E.D. being calculated at 600 r; 1 to 2 fields daily. In preliminary and postoperative irradiation only 100–120 per cent S.E.D. was given, as the object was not to destroy the cancer foci but to stimulate the tissues.—*Audrey G. Morgan.*

Hamann, A., Göbel, A., and Engelmann, K. Die Strahlenbehandlung der Gebärmutterkrebse im Allgemeinen Krankenhaus St. George in Hamburg Juni 1929 bis Dezember 1931. (The radiotherapy of cancer of the uterus in the St. George General Hospital in Hamburg from June, 1929, to December, 1931.) *Strahlentherapie*, 1934, *50*, 529–556.

The authors give tables and graphs showing the details of their results in the treatment of 476 cases of carcinoma of the uterus. Their figure for five year cures was 18 per cent, which lies at the lower boundary of the figure given by Mikulicz–Radecki at the last Berlin Gynecological Congress.

In their treatment they gave focal doses that amounted on the average to 2,300–3,000 r roentgen irradiation in the middle of the parametrium and about 1,000 to 1,200 r radium 4 cm. from the midline. Cancers which did not infiltrate the whole parametrium were therefore subjected to at least a focal dose which is equal to that given for tumors of the upper respiratory tract; in the central parts near the radium carriers it was much larger. But as a result of the great depth of the gynecological tumors the daily focal dose was smaller and for the same reason the intensity less. Therefore if the same total dose as for carcinoma of the larynx was given in cancer of the uterus and parametria with greater fractioning and protraction, the biological effect of the dose was

less though it was the same as measured in r. While a focal dose of 3,600 r given over the larynx in 18 individual doses of 200 r each with an intensity of 3.7 r/min. corresponds to 2½ erythema equivalents, the same focal dose of 3,600 r given in 22 individual doses of 120 r with an intensity of 2.2 r/min. and the addition of about 0.16 r/min. radium for 120 hours corresponds to only about 1½ erythema equivalents.

An increase of the daily focal dose to at least 200 r can be attained in the true pelvis by irradiation of two fields with an effective surface dose of 300 r each. But this protracts the daily irradiation time a great deal and is a tax on the patient because she must lie motionless so long. This as well as considerations of economy has led the authors to shorten the time of irradiation by increasing the intensity.

They have developed a more intensive method called long time intensive irradiation which since January 1932, they have used, in association with their former radium method, as the standard method of radiotherapy for cancer of the uterus.

The technique is as follows: quality of rays 1.1 to 1.7 mm. copper half-value layer; intensity of rays 20–30 r/min. surface; at focus 10/r min.; individual dose two fields with 300 r each, at the focus 200–250 r; total focal dose 2,000–2,500 r; duration of irradiation twenty-one days (each side of the pelvis thirteen days).

Focal dose of 3,600 r given by this method with 12 individual vocal doses of 200 r each in thirteen days, with the above-mentioned radium supplement, corresponds to more than 2 erythema equivalents, and, therefore, expressed in biological measurements, comes nearer to the dose given for tumors of the larnyx than does the protracted long time method, though the latter gives a larger r dosage at the focus.

In an effort not to protract the total duration of the irradiation too long, they now follow up the radium treatment immediately with the roentgen treatment, if the patient's condition permits it. With fractional radium treatment (Stockholm method) they interpose it in the three weeks' interval between the second and third radium treatment.

As to the sequence of the radium and roentgen treatment, they allow it to be determined by conditions in the individual case. If the intrauterine application of radium is possible in the beginning, this treatment is used first, even in extensive and broken down tumors, as the cervical canal often does not remain permeable after roentgen treatment because of cicatrization and retraction of the portio. They have frequently been disappointed in trying to open up access to the uterine cavity in cases in which it was blocked by tumor masses by the preliminary use of roentgen irradiation, because the contraction and rigidity of the portio and cervix caused by the roentgen irradiation created new difficulties. These difficulties increased the longer the radium treatment was deferred.

This intensive long time irradiation has the advantage over the old single treatment intensive method in that it does not cause severe general reactions or roentgen sickness. Their experience confirms that reported by Chaoul and others that of the two factors in protracted fractional irradiation the fractioning is by far the most important. Intestinal symptoms and diarrhea are rarer with this method than with protracted fractional irradiation. The skin reactions ordinarily do not go beyond the erythema stage with rather intense pigmentation; they rarely reach the stage of epidermitis sicca. Therefore another series of irradiation of the skin is possible. They systematically repeat the above-described roentgen irradiation without the addition of radium after an interval of three months. Since the introduction of this method in January, 1932, they have not seen any injury of the skin or any induration.

The therapeutic effectiveness of the intensive long time method has been demonstrated by Engelmann by means of histological studies. He found impressive pictures of very severe injury of cancer cells which exceeded those seen after the old intensive method and corresponded, to a very marked degree, to those seen after radium treatment and protracted long time irradiation.

The clinical results attained so far with this method seem to be satisfactory. It will require a longer time to compare them with those of the previous methods. This longer observation time will also show whether it is possible by this new method to obtain results in gynecological cancer comparable to those obtained by the Coutard method in carcinoma of the larynx, or whether the greater size and depth of the tumors create difficulties that will have to be overcome by a still broader knowledge of the mode of action of the rays.—*Audrey G. Morgan.*

Gál, Felix. Über Rezidive des Gebärmutterkrebses. (Recurrences of cancer of the uterus.) *Strahlentherapie*, 1934, *50*, 127–144.

The literature reports about 40 per cent of recurrences after operation for cancer of the uterus. The author reports 206 cases, among which he had 48 recurrences, or 23.3 per cent. His low percentage is probably due to the fact that in very bad cases he did not operate but treated by irradiation. He has also treated 204 cases that were operated on in other hospitals and came to him with recurrence. These recurrences are by no means hopeless. A considerable percentage of them can be cured by irradiation. Among his 48 cases 4, or 8.9 per cent, were cured and remained free of recurrence for more than five years.

The technique of irradiation in these cases is similar to that in inoperable carcinoma of the uterus. Fifty to 60 mg. radium is introduced for twenty-four hours three or four times at intervals of five weeks. The treatment is always combined with roentgen treatment, one carcinoma dose.

There was postoperative recurrence in 25.6 per cent of the carcinomas of the portio, in 57 per cent of those of the cervix and only 15 per cent of those of the body of the uterus. This is because the carcinoma more readily extends to the parametrium from the cervix. The author, as a rule, uses total vaginal extirpation. He has found that recurrence occurs as often after radical Wertheim operation as after vaginal extirpation.

He has found that roentgen irradiation alone is more effective as a prophylactic of recurrence after operation than radium alone or radium and roentgen treatment combined. Among his cases treated with radium alone there was recurrence in 35 per cent, among those treated with radium and roentgen rays in 30 per cent and among those treated with roentgen rays alone in 17.9 per cent.

He discusses the different classes of recurrences—those which come from remnants of cancer that have not been removed and those which occur after complete extirpation of the tumor because there is still a cancer predisposition. The great majority of cases, those which come from cancer cells left in the body, recur within one or two years. Among 204 cases there were 51 recurrences after six months, 126 after one to two years and 11 after three to four years. There were 16, however, after five years. These must have been from general cancer disease.

For this reason irradiation is superior to surgery as a prophylactic and treatment of cancer recurrences. The operation only removes the tumor cells but irradiation brings about profound changes in the body. It is known that immune substances, ferments, the rapidity of sedimentation of the red blood corpuscles and the endocrine glands are radically affected by irradiation. It is very probable that these changes decrease the cancer predisposition and thus lessen the chances of late recurrence.—*Audrey G. Morgan.*

Voltz, Friedrich. Weitere Ergebnisse der Strahlenbehandlung des Uteruskarzinoms. (Further results of radiotherapy of carcinoma of the uterus.) *Strahlentherapie*, 1934, *50*, 576–578.

In 1932 the author published the last material from the Döderlein Clinic; he now supplements it with the material for 1927 and 1928, for which the observation time has reached the end of the five-year period. This material shows a further improvement in results.

In 1927 and 1928, 336 cases of carcinoma of the cervix were sent to the clinic. Of these, 20 cases, or 5.9 per cent, could not be treated on account of the absolutely hopeless condition of the patients. At the end of 1933 and beginning of 1934, 76 of these patients remained alive and well. This is an absolute five-year cure of 22.6 per cent. Subtracting the untreated cases the relative cure is 24 per cent. Twenty-six out of 44 cases in Group I were cured, 28 out of 88 in Group II, 22 out of 125 in Group III, and none out of 79 in Group IV. But of the treated cases in Group IV 9 lived longer than two years and 4 longer than three years.

The total material for 1913 to 1928 was 2,202 cases. Of these, 163, or 7.3 per cent, were not treated. Of these, 395 patients were alive and well at the end of five years, or an absolute cure of 17.9 per cent. Subtracting the untreated cases, the relative figure is 19.4 per cent. The relative cure in Group I was 45.1 per cent, in Group II 24.1 per cent, in Group III 12.9 per cent. For Groups I and II the relative figure was 33.1 per cent, for Groups I, II and III it was 23.3 per cent.

In the years 1927 and 1928, 31 cases of carcinoma of the body of the uterus were sent to the clinic and all of them were treated by

radiotherapy. Of these 11 were alive and well at the end of five years. This makes a total of 138 cases of cancer of the body of the uterus treated from 1913 to 1928. The absolute figure for five-year cure is 40.6 per cent.—*Audrey G. Morgan.*

VON BÜBEN, IVAN. Ergebnisse der Strahlenbehandlung des inoperablen Kollumkarzinoms. (Results of radiotherapy of inoperable carcinoma of the cervix.) *Strahlentherapie*, 1934, *49*, 82–91.

The author discusses the results obtained in the radiotherapy of inoperable carcinoma of the cervix at the Gynecological Clinic of the Budapest University Hospital from 1919–1929. A total of 702 cases of inoperable carcinoma was treated and as some years have passed since the end of that period they have been under observation for a sufficiently long time. The cervix is connected by an abundant network of lymphatic vessels with the surrounding organs and parametrium, which accounts for the rapid progress of carcinoma of the cervix. It often reaches the limit of operability in four to six weeks. The symptoms are slight at first and that is why many of these patients do not come for treatment until they are inoperable.

The cancer cells are sensitive to the rays and a combination of radium and roentgen irradiation has proved the best treatment. Radium is used locally for the cancer and roentgen rays from outside for the treatment of the surrounding tissues. The difficulty lies in the fact that comparatively large doses of radiation must be used in a region where the surrounding tissues are also sensitive to the rays.

In the treatment of these cases, tubes containing 25 mg. radium element filtered with a silver-brass-lead filter equivalent to 1.5 mm. platinum and surrounded by a rubber ring, cork or gauze are placed in the vagina. Ordinarily 50 mg. radium is used. The irradiation time is twenty-four to forty-eight hours. The vaginal treatment is supplemented if possible by intracervical radium treatment. The cervix is carefully dilated and the radium containers placed in it. In the combined vaginal-cervical method ordinarily 4,000–6,000 mg-hr. is used. The treatment is distributed over some weeks. In advanced cases in which the radium cannot be introduced into the cervix without great destruction of tissue, vaginal treatment alone is used with smaller dosage.

In the external roentgen treatment, 3 to 6 fields are irradiated with a total dose of 1,500 r per field: radiotransverter apparatus, Cooldige tube, 190 kv., 5 ma., filter 0.5 mm. zinc and 0.5 mm. aluminum, 30 cm. focus-skin distance. The patients are examined at first every six weeks, then every three months and later every six months.

Among these 702 inoperable cases, 658 were in the third group of cases of the usual classification, or the early stage of inoperability; 44 cases were in Group IV, or advanced inoperability, practically hopeless. The results at the end of December, 1931, show that at this time among the 658 patients of Group III, 305, or 45 per cent, had been free of symptoms for over a year. Among these, 155 had been free of symptoms for one year, 68 for two years, 23 for three years, 21 for four years and 38 for five years or more. Of these 658 patients, 387 had been under observation for the five years necessary to pronounce a cure. Of these 38 were cured, or 9.8 per cent. Among these, 14 had remained well for five years, 9 for six years, 6 for seven years, 3 for eight years, 1 for nine years, 1 for ten years, 2 for eleven years and 2 for twelve years. Among the 44 hopeless cases 18 lived for a year. Among the total of 702 cases, 43.1 per cent lived for a year or more free of symptoms and 9.3 per cent could be declared cured on the basis of five years' freedom from symptoms.

The radiotherapy of inoperable carcinoma is therefore of inestimable value. Life is prolonged for from one to several years and the distressing symptoms relieved, making life tolerable or even pleasurable in cases that are otherwise hopeless, to say nothing of the 8–10 per cent of cases definitely cured.—*Audrey G. Morgan.*

BOLAFFIO, M. Über selektive Behandlung des Kollumkarzinoms. (Selective treatment of carcinoma of the cervix.) *Strahlentherapie*, 1934, *50*, 566–575.

Large series of statistics show about equal results for operation and radiotherapy of carcinoma of the cervix. But this does not mean that any case will do as well whether treated by one or the other of the methods. The author believes that the percentage of good results could be increased by studying each case individually and adapting the treatment or combination of treatments to the particular case. This will certainly be apparent to any physician who has seen a patient die of operation

who might have been saved by irradiation, or has seen rapid recurrence and death after radium treatment when it seemed probable that operation might have prevented the early recurrence.

In general, from a study of his cases the author concludes that radical operative removal of a carcinoma gives the best guarantee of permanent local recovery, provided the case is in the early clean stage with no suppuration, or if it is in an early enough stage so that it can easily be rendered clean by radium treatment.

It is more difficult to decide in cases with a purulent discharge or those in which the mobility of the uterus has been limited by extension to the parametrium. It is impossible to be certain that gland recurrences and distant metastases will be prevented either by irradiation or operation.

If it seems probable that the case can be rendered operable, that fact should be taken into consideration in giving the radium treatment. In cases in which operation is planned, not more than 3,000 to 4,000 mg-hr. should be given.

In cases that are definitely inoperable radium treatment is given with a technique adapted to the individual case, about 7,000 mg-hr. being given within a week. If the case still remains definitely inoperable after four weeks, the dose of radium may be increased to a maximum of 8,000 mg-hr.

Either operation or radium treatment is followed by a fractional roentgen treatment, adapted to the individual case.

As a general rule, the author uses a tension of about 165 kv., filter 0.7 mm. zinc, focus-skin distance 33 cm., 2 ma., compression tube 8×6 cm.; 4 to 5 skin fields, 2 in front, 2 or 3 behind and in case of very large, deep-seated tumors a Wintz vulvar field. The abdominal and possibly the vulvar fields are irradiated on one day and the back fields on the next, each field with $\frac{1}{3}$ S.E.D. (the S.E.D. equals 600 r in air); that is, in six days 1 S.E.D. is given on each field. Time of irradiation per field and per day about twenty minutes. The whole procedure is repeated 4 times in four successive weeks; but not more than 3 S.E.D. must be given on the vulvar field, because the reaction is too strong here. This treatment is carried out in full in inoperable cases; when it is given as after-irradiation after operation only three series are given.

The author has had better results so far with operation, preceded by radium and followed by roentgen irradiation than he has with irradiation alone.—*Audrey G. Morgan.*

Kirchhoff, Heinz, and Drenckhahn, J. Über die primäre Morbidität und Mortalität bei der Intensivtherapie des Carcinoma colli uteri. (Primary morbidity and mortality of intensive treatment of carcinoma of the cervix.) *Strahlentherapie*, 1934, *50*, 428–445.

The importance of knowing the primary morbidity and mortality in the treatment of genital carcinoma has been recognized in surgical treatment and taken into consideration in judging the results, but little attention has been paid to it in radium treatment. This article shows that these factors are of great importance.

The authors have collected the post-therapeutic complications, mild, severe and cases of death, among 924 genital carcinomata treated between 1922 and 1933. Of these cases 401 were operated on, 459 treated with radium and 64 were beyond treatment. The certain primary mortality after radium was 3.90 per cent, probable mortality from radium 5.2 per cent, possible 5.70 per cent. Uneventful recovery 60.3 per cent, mild complications 24.4 per cent, severe complications 9.2 per cent.

Extracts from the case histories are given showing the criteria used for determining the figures for primary mortality. Tables showing the details of the results are also given.

The certain primary operative mortality was 8.72 per cent, mortality probably due to operation 9.9 per cent; of these, 205 cases were Wertheim operations with a mortality of 15.12 per cent and 196 Schauta operations with a mortality of 2.05 per cent. Uneventful recovery 62.5 per cent, mild complications 13.2 per cent and severe complications 13.7 per cent.

A brief discussion is given of the late complications, particularly fistula, which with careful technique are very rare.—*Audrey G. Morgan.*

Dietel, F. G. Was hat die Strahlenbehandlung beim inoperablen Kollumkarzinom bisher geleistet? (What has radiotherapy accomplished so far in inoperable carcinoma of the cervix?) *Strahlentherapie*, 1934, *50*, 297–301.

The statistics heretofore have not clearly shown the results of radiotherapy in inoperable carcinomata—Groups III and IV of Döderlein's classification. The author has collected 40 groups of statistics from the world literature and finds from them that out of 7,814 inoperable cases 881 were cured for more than the five year limit, or 11.3 per cent. Though it is a matter for congratulation that 10 or 11 per cent of women with far-advanced carcinoma of the cervix can be cured, and that in a far greater percentage the symptoms can be relieved and temporary improvement brought about for two or three years, the results seem rather modest. It must be remembered, however, that these statistics include cases from the early years of roentgen therapy when the technique was not so highly developed as it is now. Some authors had particularly good statistics at that time, however, and Adler reports that his results were poorer later, probably due to the unfavorable economic conditions during the war. Weinbrenner, who used only mesothorium, had the highest number of cures in 1913 and 1914. His method was a decidedly protracted-fractional one. He gave one treatment a week for five to seven weeks with a total of 70–97 hours and 5,800 to 7,000 mg-hr. The filtration was 1 mm. gold or silver, 1.3 mm. lead or in a few cases 1 mm. aluminum.

From 30 of the statistics a comparison is made between pure radium treatment, pure roentgen treatment and mixed treatment with roentgen rays and radium. Pure radium treatment gave 246 cures out of 2,489 cases, or 9.9 per cent, pure roentgen treatment 114 out of 1,086 cases, or 10.5 per cent, and combined treatment 361 out of 2,700 cases, or 13.4 per cent. This shows that combined treatment gives the best results.—*Audrey G. Morgan.*